LA-UR-03-9155

December 2003

Approved for public release;
distribution is unlimited.

Title

A Comparison of Elk and Mule Deer Diets at Los Alamos National Laboratory in North-Central New Mexico

Author

Leonard F. Sandoval
RRES-Ecology Group
Los Alamos National Laboratory

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

An Affirmative Action/Equal Opportunity Employer

A COMPARISON OF ELK AND MULE DEER DIETS AT LOS ALAMOS NATIONAL LABORATORY IN NORTH-CENTRAL NEW MEXICO

BY
LEONARD FRANK SANDOVAL

A thesis submitted to the Graduate School

in fulfillment of the requirements

for the degree

Master of Science

Major Subject: Range Science

New Mexico State University

Las Cruces, New Mexico

December 2003

"A Comparison of Elk and Mule Deer Diets at Los Alamos National Laboratory in North-Central New Mexico," a thesis prepared by Leonard Frank Sandoval in partial fulfillment of the requirements for the degree, Master of Science, has been approved and accepted by the following:

Linda Lacey

Linda Lacey
Dean of the Graduate School

Jerry L. Holechek

Jerry L. Holechek
Chair of the Examining Committee

8 Dec 03

Date

Committee in charge:

Dr. Jerry L. Holechek

Dr. Kelly Allred

Dr. Raul Valdez

Dr. Dawn VanLeeuwen

ACKNOWLEDGMENTS

Thank you Dr. Holechek for your professional and personal guidance and support. Most of all, thank you for your patience, expertise, and encouragement.

I would also like to extend my gratitude to my committee members. Thank you Dr. Valdez for the encouragement and instruction you have provided throughout my college career. Thank you Dr. Allred for sharing your knowledge of plants with me and participating on my examination committee. Thank you Dr. VanLeeuwen for finding the time in your busy schedule to help me with the statistical analysis.

I would like to thank Carey Bare, my former team leader, and James Biggs, my former mentor, from the RRES-ECO Group at Los Alamos National Laboratory for their support and the opportunity to pursue a graduate degree. I would also like to thank Sam Loftin of the RRES-ECO Group for his expertise and time in identifying the plants with which I was not familiar. For those of you who helped in the field, you know who you are, thank you all so very much. I would also like to thank Jamus Joseph for his guidance and help in the laboratory.

To my parents, God rest their souls, thank you for bringing me up in a loving and caring family. Thank you dad for sharing your love of the outdoors with me, thanks for taking me hunting and fishing. Thank you mom for always being there. I also want to thank my family and friends for their encouragement and support. I especially want to thank my wife for her support and for always being there for me. I couldn't have done it without you.

VITA

December 23, 1969	Born at Ojo Sarco, New Mexico.
1988	Graduated from Peñasco Jr-Sr High School, Peñasco, New Mexico.
1988-1992	United States Marine Corps.
1993-1997	Under Graduate Research Assistant, Los Alamos National Laboratory, Los Alamos, New Mexico.
1997	Honors Graduate from New Mexico State University, B.S. Wildlife Science, Minor in Biology.
1998-2003	Graduate Research Assistant, Los Alamos National Laboratory, Los Alamos, New Mexico.

Professional Societies

Society For Range Management

Field of Study

Major Field: Range Science

Elk and mule deer food habits

ABSTRACT

A COMPARISON OF ELK AND MULE DEER DIETS AT LOS ALAMOS NATIONAL LABORATORY IN NORTH-CENTRAL NEW MEXICO

BY

LEONARD FRANK SANDOVAL

Master of Science

New Mexico State University

Las Cruces, New Mexico, 2003

Dr. Jerry L. Holechek, Chair

This study reports on the seasonal food habits and dietary overlap of Rocky Mountain elk (*Cervus elapus nelsonii*) and mule deer (*Odocoileus hemionus*) at Los Alamos National Laboratory (LANL) in north-central New Mexico. Seasonal food habits of elk and mule deer were determined using microhistological analysis of fecal material. Dietary overlap was calculated using Kulcyznski's similarity index. Completely randomized analysis of variance was used to determine differences in forage consumption.

Key forage species in the diets of elk and mule deer were those forage species contributing 5% or greater of the diet. Key browse (trees/shrubs) species in the diets of mule deer included mountain mahogany, oak species, Russian olive, ponderosa

pine, and skunkbush sumac. Key forb species were mullein and scarlet globemallow. Slender wheatgrass was the only grass species to contribute 5% of mule deer diets.

Key browse species in the diets of elk were oak species, ponderosa pine, and mountain mahogany. Mullein was the only key forb species. Mutton grass and June grass were two key grass species. Dietary overlap was highest between elk and mule deer during summers 1998 (71.5%) and 1999 (70.2%). Browse and forb species contributed the highest percentages of dietary overlap during all seasons of the year except during winter 1999.

Seasonal use of browse during the two-year study was greater for mule deer than elk ($P < 0.05$). Compared to mule deer, use of grasses was greater for elk during each season ($P < 0.05$). No difference in the overall seasonal use of forbs was observed ($P > 0.05$). Summer was the season with the highest overall use of browse by elk and mule deer. Overall use of grasses was also highest for elk and mule deer during winter. When comparing year 1 and year 2 no differences were observed in the overall use of browse, forbs, and grasses ($P > 0.05$).

Drought during the two-year study may have contributed to the increased seasonal use of browse and exotic drought-resistant plant species by elk and mule deer. Use of grass species by mule deer during winter may have resulted from below normal accumulation of snow and increased availability.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Increased population size and expansion of elk (*Cervus elaphus nelsonii*) in New Mexico has aroused questions concerning the management of this species. Historically, two species of elk were native to New Mexico, the southern species or Merriam's elk (*Cervus elaphus merriami*) and Rocky Mountain elk in the north (Lang 1958, Bryant and Maser 1982). At the turn of the century, both the southern and northern elk in New Mexico were extirpated as a result of western expansion into the territory, commercial market hunting, and overgrazing by domestic livestock (Lang 1958, Bryant and Maser 1982). Merriam elk were last reported in 1890 and were extirpated between 1902 and1906 (Bryant and Maser 1982). Rocky Mountain elk were last reported in 1909 (Lang 1958, Bryant and Maser 1982) and were extirpated from the Jemez Mountains before 1904 (Allen 1996).

Merriam elk was never reintroduced into New Mexico and is now extinct in North America (Bryant and Maser 1982). The earliest reintroduction of Rocky Mountain elk into the state was around 1910 on the Barlett Ranch in Colfax County (Lang 1958, Bryant and Maser 1982). Thirteen elk from Colorado in 1911 and 50 elk from Yellowstone National Park in Wyoming in 1914 were the first elk used during these early reintroduction efforts (Lang 1958, Bryant and Maser 1982). Subsequent reintroductions of elk into the Santa Fe National Forest, GOS Ranch in Grant County, TO Ranch in Colfax County, and the Tusas Mountains of Rio Arriba County were made between 1915 and 1938 (Lang 1958). Eleven shipments consisting of a total of 2,008 elk were made between 1907 and 1967 (Lindzey et al. 1997).

In 1912, there were an estimated 60 elk in New Mexico. By 1923, the northern herd numbered around 750 and by 1958 the state elk population was estimated at approximately 8,000 elk (Lang 1958, Bryant and Maser 1982). By 1976, there was an estimated 10,000 to 12,000 elk and, in 1992 around 40,000 (Bryant and Maser 1982, Allen 1996). Allen (1996) noted that if there were 11,000 elk in New Mexico in 1976 and 40,000 in 1992, the annual growth rate of the elk herd in the state would be 8.4% and the annual doubling time for the period 1976-1992 would be 8.6 years.

In 1948 the New Mexico Department of Game and Fish (NMDGF) transplanted 28 elk from Yellowstone National Park into the Jemez Mountains (Lang 1958, Allen 1996). By 1961 there were at least 200 elk in the Jemez Mountains (as cited by Allen 1996). Between 1964 and 1965 another 58 elk from Jackson Hole, Wyoming, were released into the southwest portion of Los Alamos County adjacent to Bandelier National Monument (BNM) (White 1981).

The La Mesa fire in 1977 created 6,070 hectares of potential elk wintering range with 1,214 hectares of this wintering range on Los Alamos National Laboratory (LANL) (White 1981). White (1981) predicted that use of this wintering habitat by elk would result in problems with overpopulation of elk herds. By 1989, the number of elk in the Jemez Mountains was estimated between 6,000 and 8,000 (Allen 1996). Assuming that the elk herd grew from 28 in 1948 to an estimated 7,000 in 1992, the calculated annual growth rate of the elk herd in the Jemez Mountains would be 13.4% and the doubling time for the population would be 5.5 years (Allen 1996).

In 1989, wintering populations of elk on BNM, LANL, and adjacent Santa Fe National Forest lands were estimated to be between 1,000 to 2,000 (Allen 1996). Since 1990, annual helicopter counts suggest that at least 1,500 elk winter on BNM (Allen 1996). Large numbers of elk also winter on LANL property and there is evidence of year-round use in all technical areas since the early 1990s (Gonzales et al. 1995).

Also of growing concern in New Mexico and across the southwest is an increased interest in the decline of mule deer (*Odocoileus hemionus*) populations. During pre-Columbian times it was estimated that as much as 5 million mule and black-tailed deer (*Odocoileus hemionus*) occurred in the western United States (Lindzey et al. 1997). Habitat destruction caused by human settlement, heavy grazing, droughts, severe blizzards, and conversion of habitat to agriculture led to widespread declines in mule deer populations, and, by the early 1900s, mule deer were considered scarce throughout much of the West (Lindzey et al. 1997).

From the 1920s until 1976, mule deer populations in the west tended to follow a pattern of gradual buildup of herds beginning in the 1920s, peaks in the late 1940s to early 1960s (Lindzey et al. 1997), then a general decline during the 1960s, continuing to 1976 (Connolly 1981). Lang (1957) noted that in 1926, deer in New Mexico numbered around 41,000 and that combined numbers of mule deer and white-tailed deer (*Odocoileus virginianus*) in 1956 were around 300,000. In New Mexico, mule deer populations declined approximately 32% between 1967 and 1975, dropping from about 405,000 to 276,000, with most of the decline occurring in the northern part of the state (Connolly 1981, Short 1979, Synder 1976).

Estimates on United State Forest Service (USFS) lands from 13 western states indicated that mule deer numbers increased from 1950 through 1962, remained near peak levels through 1965, declined slightly from 1966 through 1971, then dropped more rapidly after 1971 (Connolly 1981). USFS totals for mule deer and black-tailed deer in 1976 show a 38% decrease from the peak in 1962 (Connolly 1981). Estimates on USFS property in New Mexico for mule deer populations were 53,000 in 1950, peaked at 135,000 in 1965, then fell to 111,000 in 1976 (Connolly 1981).

No accurate estimates of mule deer numbers currently exist for New Mexico and, according to the mule deer biologist for the state, mule deer numbers have been at a steady decline from peaks in the 1960s to an estimated 110,000 to 120,000 mule deer across the state (B. Hale, 2002 personal communication). Noted causes of declines in mule deer numbers across New Mexico include increased fire suppression in the past 50 years, increased protection of mountain lions, less predator control, and the outlawed use of Compound 1080 (B. Hale, 2002 personal communication).

In Los Alamos County elk have become an important traffic hazard (Burns 1992) with two-thirds of all elk-related accidents initially occurring in the fall and winter (Biggs et al. 2000, Gonzales et al. 1995). The hazards of elk-related accidents in Los Alamos County are now present year-round and affect roads through low-elevation woodlands (Gonzales et al. 1995). There were at least 51 accidents between January 1990 and February 1995 involving elk (Gonzales et al. 1995). In a memo to LANL, the Los Alamos Police Department identified elk and mule deer vehicle collisions as a major problem on county roads in Los Alamos (Biggs et al. 2000).

Between 1990 and 1999 there were 107 elk-related and 125 mule deer-related accidents on LANL with most of these vehicle collisions occurring during late afternoon and evening hours (Biggs et al. 2000). Elk and mule deer on LANL also pose a number of other concerns relating to property damage, radiological contamination, and habitat degradation.

At LANL, studies have been conducted to determine the movement patterns of elk using VHF (very high frequency) and GPS (global positioning system) collars (White 1981, Biggs et al. 1999). Estimates of the exact numbers of elk and mule deer on LANL property are currently nonexistent. Also lacking on LANL property is information on the food habits of elk and mule deer. An understanding of the seasonal diets of elk and mule deer on LANL is necessary for the management of these species.

According to Kufeld (1973) and Hunt (1979), knowledge and understanding of food habits are fundamental for the interpretation of an animal's behavior, physiology, ecology, and morphology. More importantly, they are essential in the management of large ungulates for evaluating diet quality, preference, and competition (Nelson and Leege 1982). Knowledge of seasonal food habits is also the basis for understanding and evaluating range carrying capacity of large herbivores such as elk and mule deer (Leslie et al. 1984).

Previous food habits studies of elk and mule deer in the area surrounding LANL include three studies conducted on Bandelier National Monument. Potter and

Berger (1977) documented competition between mule deer and burros. A second study by Rowland et al. (1983) was conducted following the La Mesa fire of 1977 to determine winter diets of elk. Wolters (1993) quantified current vegetation composition, forage production, use, and preference of herbage by elk on a seasonal basis in two different habitat types.

No further studies on the diets of elk or mule deer have been conducted on the Pajarito Plateau, including LANL. Furthermore, no studies in the area have been conducted to simultaneously evaluate the diets of elk and mule deer. Information on the food habits and dietary overlap between elk and mule deer for forage during different seasons of the year is of interest to LANL resource managers. As part of this study, the seasonal diets of elk and mule deer were determined through microhistological analysis of fecal material. Fecal analysis was chosen because it is inexpensive, practical, and accurate for evaluating diet composition of large herbivores (Anthony and Smith 1974, Gretchen and Dahl 1980, Sanders et al. 1980, Johnson and Person 1981, Kessler et al. 1981, Mohammad et al. 1995).

The objectives of this study were to 1) determine the seasonal diets of elk and mule deer on LANL and 2) determine dietary overlap of elk and mule deer during different seasons of the year for two years.

STUDY AREA

The study area is located on LANL. LANL is located in north-central New Mexico approximately 128 kilometers north of Albuquerque and 40 kilometers northwest of Santa Fe. LANL covers approximately 69 square kilometers of land and is located on the Pajarito Plateau on the eastern flanks of the Jemez Mountains. The easternmost extension of the Pajarito Plateau consists of several fingerlike mesas and canyons, which run along the plateau slope line and eventually are bounded to the east by the Rio Grande. LANL is largely, but not completely, surrounded by Los Alamos County to the north, bordered to the south by Bandelier National Monument, USFS property to the west, and on the east by the Pueblo of San Ildefonso. Two populated areas, Los Alamos town site and White Rock town site, are adjacent to LANL to the north and southeast (Figure A1).

LANL has a semiarid, temperate mountain climate (Bowen 1990). Summer temperatures in the afternoons are usually between 21 to 27 degrees Celsius and occasionally reach 32 °C. Nighttime temperatures drop to 10 °C even after the warmest days. Winter temperatures typically range from -9 °C to -4 °C during the night and from -1 °C to 10 °C during the day.

Typically, the greatest amount of rainfall is received during the warmest months of the year, usually from June to August. In the study area, more than half of the annual precipitation is received between May and October, with 36% or more falling during the height of the monsoon season in July and August (Bowen 1990). The peak rainfall month is August with thundershowers developing over the Jemez

Mountains during the afternoons and early evenings and drifting out over the Pajaritio Plateau, causing brief, but intense rains. Winter precipitation falls as snow, with accumulations of about 150 centimeters seasonally (Bowen 1990). Average annual precipitation at Los Alamos town site, including rainfall and snowfall precipitation is 48 centimeters. Annual variations in precipitation levels for Los Alamos range from 17 to 77 centimeters over a 71-year period (Bowen 1990). Seasonal snowfall level extremes for the same time period ranged from 24 to 389 centimeters (Bowen 1990).

Temperatures in the study area for 1998 were above average for May, June, September, November, and December. All other months of the year were at or below average temperatures. Total monthly precipitation in the study area for 1998 was above average for March, July, and October with all other months of the year having below average precipitation. Total monthly snowfall in the study area for 1998 was below average. Total annual precipitation in the study area for 1998 was 44 centimeters and total annual snowfall was 29 centimeters (LANL 2001).

Temperatures in the study area for 1999 were above average for January, February, March, September, October, and November. All other months of the year were at or below average temperatures. Total monthly precipitation in the study area for 1999 was above average for March, April, May, June, and September with all other months of the year having below average precipitation. Total monthly snowfall in the study area for 1999 was above average for March and April with all other months of the year having below normal snowfall. Total annual precipitation in the study area for 1999 was 41 centimeters, and total annual snowfall was 73 centimeters (LANL 2001).

Spring temperatures in the study area for 2000 were above average. Total monthly precipitation in the study area for spring 2000 was below average. Total annual precipitation in the study area for 2000 was 35 centimeters, and total annual snowfall was 71 centimeters (LANL 2001).

The elevation range of the study area is approximately 1,981 to 2,286 meters. The lowest elevation range extends just to the northeast edge of White Rock town site along Pajarito Road and the higher elevation range extends just to the southwest boundary of LANL along Highway 501 (Figure A1).

Piñon-juniper (*Pinus edulis-Juniperus monosperma*) woodlands are the dominant vegetation between 1,767 and 2,134 meters (Tierney and Foxx 1980, Balice et al. 1997) (Figure A2). Piñon-juniper woodlands range from open to closed canopy communities (Tierney and Foxx 1984) and can be found as high as 2,194 meters on south-facing slopes (Balice et al. 1997). The dominant tree species are one-seed juniper and piñon pine, one-seed juniper being dominant at lower elevations, and piñon pine dominant at higher elevations (Balice et al. 1997). On mesa tops where one-seed juniper is the dominant tree species, tree density is 33 to 176 trees/hectare (Foxx 1996). Piñon pine tree density on these mesa tops is 4 to 95 trees/hectare (Foxx 1996). Other tree species are absent or rare. The most common shrubs are oaks *(Quercus gambelii* and *Quercus undulata)*, mountain mahogany *(Cercocarpus montanus)*, wormwood *(Artemesia ludoviciana*), skunkbush sumac *(Rhus trilobata),* and wax currant *(Ribes cereum)*; Tierney and Foxx (1982). Common grasses are blue grama *(Bouteloua gracilis)*, needle and thread grass *(Stipa comata),* galleta *(Hilaria* *jamesii)*, ring muhly *(Mulenburgia torreyi),* and mountain muhly *(Mulenbergia montana)*; Tierney and Foxx (1982), Balice et al. (1997). Common forbs include bitterweed *(Hymonoxys argentea),* white ragweed *(Hymenopappus filfolius),* and leafy golden aster *(Chrysopis villosa)* (Tierney and Foxx 1982).

Ponderosa pine (*Pinus ponserosa*) forests extend from 1,890 to 2,377 meters and occupy the western one-third of LANL (Tierney and Foxx 1982, Balice et al. 1997) (Figure A2). Ponderosa pine is the dominant tree species and range from doghair thickets to open stands. Ponderosa pine tree density in canyon bottoms within the study area varies between 87 to 103 trees/hectare (Biggs 1996, Raymer 1996). One-seed juniper and piñon pine can be present at lower elevations, but other tree species are typically absent or rare (Balice et al. 1997). The understory is composed mostly of grasses and sedges, such as mountain muhly, little bluestem *(Schyzachyrium scoparium)*, pine dropseed *(Blepharneuron tricolepis),* wild mountain sedge *(Carex geophila),* and wheatgrass species *(Agropyron* species*)*; Tierney and Foxx (1982), Balice et al. (1997). Gambel's oak *(Quercus gambelii),* bearberry *(Arctostaphylos uva-ursi),* and Colorado barberry *(Berberis fendleri)* are the three most common shrubs. Common forbs include pussytoes *(Antennaria parvifolia)* and Fremont's goosefoot *(Chenopodium fremontii)*.

Past disturbance in the study area and Pajarito Plateau included grazing by sheep, cattle, goats, and horses from as early as the 16^{th} century until the mid-1940s (Tierney and Foxx 1982). Agriculture in the higher regions of the Pajarito Plateau began in the late 1800s and continued until the mid-1940s when the federal government appropriated homesteads in the area. The Pajarito Plateau has also been subjected to heavy logging from near the turn of the century until the mid-1940s (Tierney and Foxx 1982). The area that is now LANL has not been exposed to hunting since the mid-1940s as well. Selection of the site for the then secret Manhattan Project in 1942 influenced land use on the Pajarito Plateau by clearing land for utilities, homes, buildings, roads, parking lots, and what is today known as LANL (Tierney and Foxx 1982).

The last major fire in the 19th century on the Pajarito Plateau was in 1893 (Foxx 2000). Fire suppression on the Pajarito Plateau led to several large fires. The first large-scale fire of the 20th century was the La Mesa fire of 1977, followed by the Dome fire of 1996, the Oso fire of 1998, and the Cerro Grande fire of 2000. The La Mesa fire of 1977 burned 5,036 hectares of land on Bandelier National Monument and 1,214 hectares on LANL (White 1981, Foxx 2000). The Dome fire of 1996 burned 6,475 hectares of land on the Pajarito Plateau and the Oso fire of 1998 another 2,023 hectares (Foxx 2000). The Cerro Grande fire of 2000 burned roughly 17,462 hectares of land on the Pajarito Plateau with approximately 3,096 hectares within the boundaries of LANL (Foxx 2000). In the past 25 years over 32,375 hectares of forested land has been burned by wildfires on the Pajarito Plateau and east Jemez Mountains.

MATERIALS AND METHODS

Field Techniques

Establishment of Pellet Plots

Movement and distribution data collected from radio-collared elk captured on LANL between 1996 and 1998 (Biggs et al. 1999) were used to help determine locations for the placement of pellet plots. No radio-collar data exist on the movements and distribution of mule deer within the study area. Mesa tops and canyon bottoms in areas identified as having use by elk and mule deer during at least part of the year were selected for establishment of permanent pellet plots.

Elk and mule deer use within the study area was determined by the presence of old tree rubs, game trails, bedding areas, tracks, pellets, and previous browsing on shrub species. During summer 1998, thirteen permanent pellet plots were randomly placed on mesa tops and in canyon bottoms dominated by piñon-juniper or ponderosa pine (Figure A3). Pellet plots were 20 m by 20 m and marked at each corner with a permanent metal rebar stake. Twenty-meter by 20 m pellet plots were used because a previous study conducted on LANL showed no significant differences in the number of pellet samples collected for elk and mule deer comparing circular plots to pellet plots (Unpublished data).

Collection of Pellet Samples

Pellet samples were collected four times each year. Seasons were designated as: Summer (June 16th thru Sept. 15th), Fall (Sept. 16th thru Dec. 15th), Winter (Dec. 16th thru March 15th), and Spring (March 16th thru June 15th). At the beginning of each season, the 13 pellet plots were cleared of any existing fecal material by crushing it into the ground with the bottom of your boot. This was done to avoid re-sampling the same pellets the following season.

Collection of pellet samples was initiated during summer 1998 and completed during spring 2000. Pellets were collected in the middle and end of each season. Color and moisture of pellets were used to estimate age of the pellet groups so that only pellet groups of that season would be collected (Freddy 1983). By collecting pellet samples in the middle and end of each season, and taking color and moisture content of the pellets into consideration, collected pellet samples were considered representative of that season. Collecting pellets towards the middle or end of a season also ensured that plant material in the feces was representative of that season.

During the collection of pellet samples, size and shape of pellets were used to differentiate between the pellets of elk and mule deer (Bubenik 1982). For each collection period at least five pellets from every pellet group encountered were collected and placed in labeled paper bags. After each collection period, all remaining pellets were crushed into the ground. This helped ensure that the same pellets would not be collected twice per season. If no pellet samples were found within the plot, a systematic search immediately surrounding the plot was conducted and pellets from all fresh pellet groups were collected. All remaining pellets from these collections were crushed to avoid double sampling in subsequent collection efforts.

The objective was to collect five pellets from at least five pellet groups per season for both elk and mule deer at each of the 13 pellet plots. Total pellet samples collected during each sampling period were much lower than expected, especially for mule deer. Because not all pellet plots met the above criteria for each season, pellet samples of elk from three pellet plots per season were combined individually and used as three samples for that season (Holechek 1999, personal communication). Pellet plots with three or more pellet groups per season were selected for fecal analysis of elk diets (Tables B1 & B2).

Mule deer on the other hand did not have three pellet plots per season for all seasons of the year with three or more pellet groups. Therefore, pellet samples of mule deer from those seasons with two pellet plots and at least two pellet groups per season would be combined individually and used as two samples for those seasons (Holechek 1999, personal communication). Pellet samples of mule deer from those seasons of the year with three pellet plots and three or more pellet groups per season were also combined individually and used as three samples for those seasons. Pellet plots meeting the above criteria were selected for fecal analysis of mule deer diets (Tables B1 & B2).

Collection of Reference Plants

Collection of reference plants was also initiated during summer 1998 and continued through the duration of the food habits analysis of elk and mule deer diets. The leaves, twigs, flowers, and fruits of actively growing shrubs and whole shoots or parts of forbs and grasses reported in previous studies as constituting the diets of elk and mule deer (Lang 1957, Lang 1958, Kufeld 1973, Kufeld et al. 1973, Potter and Berger 1977, Short et al. 1977, Wallmo and Regelin 1981, Nelson and Leege 1982, Rowland et al. 1983, Wolters 1993, Joseph 1995) were reference plant species collected. Plant species commonly encountered within each of the pellet plots and other plant species encountered during each season were also collected.

Plants that were unidentifiable at the time of vegetation sampling were collected, labeled, and identified by comparing with specimens in the Ecology Group’s herbarium at LANL. Sufficient quantities of each plant species were collected for making reference slides for microhistological analysis (Holechek 1982, Mower and Smith 1989). Plants were also identified by referencing Foxx and Hoard (1984), DeWitt Ivey (1995), Foxx and Hoard (1995), Stubbendieck et al. (1997), Carter (1997), and Racinez and Foxx (1999).

Laboratory Techniques

Sample Processing

Pellet samples collected from two or more pellet plots that had at least two or more pellet groups each season for both elk and mule deer were dried in drying ovens at 60 °C for 24 hours and then ground to pass through a 1 mm screen using a Wiley-mill grinder (Todd and Hansen 1973, Gretchen and Dahl 1980) in the Ecology Group’s food contaminants laboratory at LANL. Ground pellet samples were stored in labeled zip-lock bags until they were needed for slide preparation. All collected reference plant samples were also oven-dried at 60 °C for 24 hours and ground to pass through a 1-mm screen using a micro-mill grinder. Ground plant samples were stored in labeled plastic vials until needed for slide preparation.

Preparation and Storage of Mounting Medium

Preparation of mounting medium followed the procedure outlined by Joseph (1995) and Mangold (1997). Aqueous Kaiser glycerine jelly was prepared using 8 g of gelatin soaked in 52 ml of water for 1 to 2 hours in a polyethylene plastic container followed by the addition of 50 ml of glycerine and 0.01g of Thimerosal preservative. The mixture was heated in a water bath at 65 to 75 °C for 10 to 15 minutes and stirred until a homogeneous jelly was formed. The homogeneous jelly was stored in a refrigerator.

Slide Preparation

Preparation of reference slides from ground plant material and slides from ground pellet samples were prepared using the method developed by Sparks and Malechek (1968) as modified by Holechek (1982) and Alipayo et al. (1992). Mounting of slides was done with the use of Kaiser glycerine jelly and based on the procedure described by Joseph (1995).

One to two spatulas of ground plant material or ground pellet sample were soaked in 30 ml of boiling water for 10 minutes. Following soaking, the ground material was placed in a No.120-size mess sieve and rinsed with hot tap water for 3 to 5 minutes to remove dirt and fine plant particles. After rinsing, the ground material was soaked in 20 ml of bleach for 5 minutes to remove plant pigments and stains. The ground material was then re-rinsed in the sieve with hot tap water until the odor of bleach disappeared. Excess water from the ground material was then removed by gathering it in a lump on the sieve and squeezing water from it by firmly pressing with the back of a spatula. A small amount of the ground material was removed from the sieve and packed with the plastic end of a teasing needle into the 5 ml wide hole of a lead slab pre-positioned on a clean microscope slide. This ensured that equal amounts of the ground material would be used in the preparation of all slides. Excess water from the sample of ground material in the 5 ml hole was removed with a paper towel to help avoid formation of air bubbles between the microscope slide and glass cover slip.

The sample of ground material was then placed in the center of a clean microscope slide by pushing it through the hole on the lead slab with a teasing needle. A glass eyedropper was used to add 14 drops of Kaiser glycerine jelly to the sample on the slide. The Kaiser glycerine jelly had to be heated until the jelly became an aqueous solution. The aqueous solution thickens rapidly on exposure and therefore was kept in a warm water bath to remain aqueous. Once the mounting jelly was applied onto the slide the sample was mixed quickly with a teasing needle until fragments in the sample were uniformly distributed. The mixture was rapidly and evenly spread with the teasing needle across the slide to cover an area the size of a 22 by 44-mm glass cover slip. A cover slip was then lowered at an angle over the mixture and dropped onto the slide. Three reference slides were mounted for each plant species collected and five slides for every combined sample per season of pellets collected at two or three pellet plots.

Slides were stored in slide holders so that they remained level until the mounting jelly dried. After the mounting jelly dried, the cover slip was sealed with a thin layer of clear nail polish and allowed to dry for 24 hours. This prevented air from getting underneath the cover slip and extended the life of the slide.

Fecal Analysis

The seasonal diets of elk and mule deer were determined using microhistological analysis of feces (Dearden et al. 1975, Alipayo et al. 1992). A total of 235 slides were analyzed (5 slides/pellet-plot $\times$ 2 to 3 pellet-plots/species $\times$ 2 species of ungulates $\times$ 8 seasons). Fifteen slides per season for each ungulate species, with the exception of only 10 slides for mule deer during spring 1999, were analyzed by systematically viewing 20 fields at 100 to 200X magnification for each slide (for a total of 100 fields per sample) under a compound phase-contrast binocular microscope (Sparks and Malachek 1968, Todd and Hansen 1973, Gretchen and Dahl 1980). Frequency for each set of five slides was determined using the frequency addition method developed by Holechek and Gross (1982a).

Diagnostic characteristics for identification of plant species in the diets of elk and mule deer included observing differences in the configuration of the cell wall, size and shape of the stoma and its subsidiary cells, presence or absence of trichomes, and, in grass species, presence of cork and silica cells (Martin 1954, Sparks and Malachek 1968, Hansen et al. 1971, Potter 1977, Howard and Samuel 1979, Gretchen and Dahl 1980, Green et al. 1985). Trichomes were an outstanding character by which forbs were identified under the microscope because they exhibit distinctive shapes, are not easily digested, and are either unicellular or multicellular (Gretchen and Dahl 1980). In woody species trichomes are generally unicellular, with *Quercus* species being the exception. Both Gambel's and wavyleaf oak were present on the study area, but could not be discerned separately by epidermal characteristics. All structures on the microscope slide were required to be attached to epidermal cells in order to be counted to prevent over-or underestimation of some species. Fragments in all slides were identified to species, genus, or lifeform.

The observer was trained using the method described by Holechek and Gross (1982b). Observer accuracy was tested using hand-compounded diets (Holechek et al. 1982). Observer accuracy was estimated at 90% for plant identification and qualification. Percent composition (frequency of occurrence) was determined for each plant species using the formula: $\mathbf{PC = A \times 100/B}$, where A is the occurrence of each plant species and B is the occurrence of all plant species in the diet (Sparks and Malachek 1968, Alipayo et al. 1992). For the purpose of this study, the percent composition of each set of five slides (fifteen slides per season) was calculated as described in the previous sentence and then averaged to determine the percent botanical composition in each of the diets. Plant species were divided into forage classes of grasses, forbs, and browse, with tree and shrub species classified as browse.

Dietary overlap of seasonal diets between elk and mule deer was calculated using Kulcyznski's similarity index (Oosting 1956, Hubbard and Hansen 1976, Hansen and Clark 1977, Kingery et al. 1996). Kulcyznski's similarity index has been used almost exclusively for quantitative evaluation of similarity and overlap of range herbivore diets (Holechek et al. 1984). The formula used to determine dietary overlap was: **$S = (2)(W)(100)/ (A + B)$,** where S represents the similarity in diets, W represents the sum of the quantity of each plant species that the two diets have in common, A represents the total quantity or number of all species in diet (a) and B represents the total quantity of all species in diet (b) (Holechek et al. 1984). Diet (a) represented the diets of elk and diet (b) represented the diets of mule deer for each season. Seasonal dietary overlap was computed for paired animal species/plant species combinations over all seasons. For the purpose of this study, the similarity index represented the percentages of two diets that were identical for each season.

Statistical Analysis

Statistical analysis was conducted at New Mexico State University (NMSU) through the Agricultural Biometric Service. The model involved using SAS (SAS Institute Inc. 1999) to conduct a completely randomized analysis of variance to determine differences in forage consumption between elk and mule deer diets and included species, year, and seasonal comparisons as well as within species and within season comparisons.

First, a review of the forage species found in both diets was conducted to determine which of these forage species were common use species in elk and mule deer diets. Based on the review, common browse included one-seed juniper, oak species, mountain mahogany, Apache plume (*Fallugia paradoxa*), skunkbush sumac, and ponderosa pine. Common forbs in both diets included mullein (*Verbascum thapsus*), annual sunflower (*Helianthus annuus*), scarlet globemallow (*Sphaeralcea* *coccinea*), and purple prairie clover (*Petalostemum purpureum*). Two common grass species in both diets were slender wheatgrass (*Agropyron trachycaulum*) and orchard grass (*Dactylis glomerata*). Common forage species were analyzed to determine differences in the consumption of these forage species between elk and mule deer diets as well as to assess seasonal and year effects. Totals of the three forage classes were also analyzed to determine seasonal differences in forage consumption between elk and mule deer diets.

Means were obtained for elk and mule deer diets by individually pooling across seasons and years to describe a species effect during the two-year study. Cover data, also part of the species effect, was pooled from previous surveys conducted at eight locations within the study area and used to show percent cover of primary forage species (Biggs 1996, Foxx 1996, Raymer 1996, Salisbury 1995). Percent cover of browse was collected using the line intercept method along 100 ft line transects. Percent cover of forbs and grasses was collected along the same line transect at every 10 ft using a 20 X 50 cm daubenmire to visually estimate cover. To show a year effect, diets of elk and mule deer were pooled across animal species and seasons. Pooling elk and mule deer diets across animal species and years was done to show a season effect. Diets of elk and mule deer were also individually pooled across years to show a species X season effect. Pre-planned comparisons with the species X season effect involved conducting within species comparisons of elk and mule deer diets. Within season comparisons of elk and mule deer diets were also conducted with the species X season effect.

RESULTS AND DISCUSSION

Species Effect

The seasonal diets of mule deer on LANL during the two-year study period included 12 browse, 10 forbs, and 4 grasses. Seasonal diets of elk on LANL during the two-year study period consisted of 14 browse, 12 forbs, and 14 grass or grasslike plants. Key forage species in the diets of elk and mule deer were those forage species contributing 5% or greater of the diet. Key browse species in the diets of mule deer consisted of mountain mahogany, oak species, Russian olive (*Elaeagnus angustifolia*), ponderosa pine, and skunkbush sumac in the order from highest to lowest contribution to the diet (Table 1). Elk key browse species included oak species, ponderosa pine, and mountain mahogany also in order from highest to lowest contribution to the diet (Table 1). Oak species, mountain mahogany, and Russian olive use by elk and mule deer within the study area met or exceeded the percent cover of these browse species (Table 1). Use of skunkbush sumac by mule deer also exceeded percent cover.

Mullein was the only key forb species in the diets of elk. While key forb species in the diets of mule deer were mullein and scarlet globemallow. Use of mullein and scarlet globemallow by elk and mule deer within the study area exceeded percent cover of these forb species (Table 1). Mutton grass (*Poa fendleriana*) and June grass (*Koelaria macrantha*) were two key grass species in the diets of elk and use of these grasses by elk exceeded percent cover. Blue grama grass made up 10% of the available grass species yet only traces of this grass were found in the diets of

Table 1. Percent cover of the primary forage species and there mean percent contribution to elk and mule deer diets.

Lifeform/species	Percent Cover	Elk	Mule Deer
One-seed Juniper *(Juniperus monosperma)*	8.3%	1.5%	4.2%
Oak species *(Quercus species)*	11.5%	11%	13.2%
Mountain Mahogany *(Cercocarpus montanus)*	4.1%	5.2%	16.1%
Apache plume *(Fallugia paradoxa)*	3.2%	3.1%	3.2%
Russian olive *(Elaeagnus angustifolia)*	1.4%	3.8%	11.5%
Skunkbush sumac *(Rhus trilobata)*	3.2%	1.7%	6.3%
Pinon pine *(Pinus edulis)*	11%	T	2.4%
Fourwing saltbush *(Atriplex canescens)*	T	T	T
Buckbrush *(Ceanothus fendlerii)*	0%	0%	T
Coyote willow *(Salix exigua)*	5%	2.3%	0%
Douglas fir *(Pseudotsuga menziesii)*	0%	1.3%	1%
Ponderosa pine *(Pinus ponderosa)*	15%	9.4%	8.7%
Rubber rabbitbrush *(Chrysothamnus nauseosus)*	2%	T	T
Big sagebrush *(Artemisia tridentata)*	3%	1.9%	0%
Narrowleaf yucca *(Yucca angustissima)*	T	1%	0%
Total Browse	**68%**	**44%**	**67%**
Mullein *(Verbascum thapsus)*	T	9.2%	6.8%
Annual sunflower *(Helianthus annuus)*	0%	1.9%	2.1%
Scarlet globemallow *(Spaeralcea coccinea)*	0%	4.4%	6%
White sweet clover *(Melilotus albus)*	T	1.3%	1.9%
Deer vetch *(Lotus wrightii)*	0%	1.1%	1.5%
Aster species *(Aster species)*	1.4%	T	T
Purple prairie clover *(Petalostemum purpureum)*	0%	2%	4%
Goldenrod species (*Solidago* species)	0%	T	0%
Fringed sagebrush *(Artemisia frigida)*	0%	1.5%	1%
Fleabane species *(Erigeron species)*	T	T	2%
Tansy mustard *(Descurainia richardsonii)*	0%	T	0%
Bladderpod species *(Lesquerella species)*	0%	0%	1%
Unid Forb species	0%	2%	1.5%
Total Forbs	**3%**	**25%**	**28%**
Canaryreed grass *(Phalaris arundinacea)*	0%	3.8%	0%
Cheat grass *(Bromus tectorum)*	T	T	0%
June grass *(Koelaria macrantha)*	T	6.2%	0%
Longstyle rush *(Juncus longystylus)*	0%	1.5%	0%
Carex species *(Carex species)*	8.3%	T	0%
Slender wheatgrass *(Agropyron trachycaulum)*	T	4%	2.2%
Mutton grass *(Poa fendleriana)*	5.9%	7%	0%
Fescue species *(Festuca species)*	0%	4.6%	0%
Blue grama grass *(Bouteloua gracilis)*	10%	T	T
Smooth brome *(Bromus inermis)*	1.3%	1.4%	T
Little bluestem *(Schizachyrium scoparium)*	2.7%	T	0%
Flatsedge species *(Cyperus species)*	0%	T	0%
Foxtail barley *(Hordeum jubatum)*	T	T	0%
Orchard grass *(Dactylis glomerata)*	0%	2.8%	1.5%
Total Grasses	**29%**	**31%**	**5%**

Cover data were pooled from previous surveys conducted at 8 locations within the study area (Biggs 1996, Foxx 1996, Raymer 1996, and Salisbury 1995).
Diets were pooled across seasons and years.
T = Trace.

elk (Table 1). When pooled across seasons and years, no single grass species contributed 5% or greater of mule deer diets. Slender wheatgrass was the only grass in the diets of mule deer contributing greater than 2% of the diet (Table 1). Forage species contributing less than 1% of the diet were considered traces.

Overall use of browse was significantly greater for mule deer than elk ($P < 0.05$) (Tables 1, C1, & C5). Differences were observed ($P < 0.05$) in the use of one-seed juniper, mountain mahogany, Russian olive, and skunkbush sumac between elk and mule deer diets, with mule deer having the highest overall use of these browse species. Common use of oak species and ponderosa pine by elk and mule deer revealed no differences ($P > 0.05$). No differences were observed in the overall use of forbs ($P > 0.05$). Overall use of grasses by elk was significantly greater than mule deer ($P < 0.05$).

Year Effect

When pooled across animal species and seasons the combined diets of elk and mule deer on LANL showed no significant increases in the overall use of browse, forbs, and grasses between both years ($P > 0.05$) (Tables 2, C1, & C6). Skunkbush sumac and scarlet globemallow were the only two forage species with an increase in use ($P < 0.05$) from year 1 to year 2 (Tables 2, C1, & C6).

Season Effect

When pooled across animal species and years the combined diets of elk and mule deer on LANL revealed that summer was the season of highest overall browse use (Table 3). There was a decline in the overall use of browse between summer and fall ($P < 0.05$) (Tables 3, C1, & C7).

Table 2. Mean percent contribution of the primary forage species comparing year 1 and year 2.

Lifeform/species	Year 1	Year 2
Browse		
One-seed Juniper *(Juniperus monosperma)*	3%	2.9%
Oak species *(Quercus species)*	10.6%	13.1%
Mountain Mahogany *(Cercocarpus montanus)*	8.5%	12.8%
Apache plume *(Fallugia paradoxa)*	4.3%	1.9%
Russian olive *(Elaeagnus angustifolia)*	6.6%	8.7%
Skunkbush sumac *(Rhus trilobata)*	2.2%	5.8%
Buckbrush *(Ceanothus fendlerii)*	T	0%
Pinon pine *(Pinus edulis)*	2.4%	T
Coyote willow *(Salix exigua)*	1.1%	1.1%
Douglas fir *(Pseudotsuga menziesii)*	1.3%	1%
Narrowleaf yucca *(Yucca angustissima)*	T	T
Ponderosa pine *(Pinus ponderosa)*	9.3%	8.9%
Fourwing saltbush *(Atriplex canescens)*	1.3%	1.8%
Rubber rabbitbrush *(Chrysothamnus nauseosus)*	0%	1.4%
Big sagebrush *(Artemisia tridentata)*	1.9%	0%
Total	**53%**	**59%**
Forbs		
Mullein *(Verbascum thapsus)*	7.7%	8.3%
Annual sunflower *(Helianthus annuus)*	2.4%	1.6%
White sweet clover *(Melilotus albus)*	2%	1.2%
Deer vetch *(Lotus wrightii)*	2%	T
Aster species *(Aster species)*	T	0%
Scarlet globemallow *(Spaeralcea coccinea)*	2.5%	8%
Purple prairie clover *(Petalostemum purpureum)*	3.3%	2.5%
Goldenrod species *(Solidago species)*	T	0%
Fringed sagebrush *(Artemisia frigida)*	2.5%	T
Fleabane species *(Erigeron species)*	1.9%	T
Tansy mustard *(Descurainia richardsonii)*	T	0%
Bladderpod species *(Lesquerella species)*	T	T
Unid Forb species	1.1%	2%
Total	**28%**	**24%**
Grasses		
Mutton grass *(Poa fendleriana)*	4%	2.6%
Canaryreed grass *(Phalaris arundinacea)*	1.6%	2.2%
June grass *(Koelaria macrantha)*	2%	3.3%
Fescue species *(Festuca species)*	2.8%	1.7%
Carex species *(Carex species)*	T	0%
Slender wheatgrass *(Agropyron trachycaulum)*	2.7%	3%
Longstyle rush *(Juncus longystylus)*	T	1%
Cheat grass *(Bromus tectorum)*	T	0%
Smooth brome *(Bromus inermis)*	T	1.4%
Blue grama grass *(Bouteloua gracilis)*	T	T
Orchard grass *(Dactylis glomerata)*	3%	1.5%
Flatsedge species *(Cyperus species)*	T	0%
Little bluestem *(Schizachyrium scoparium)*	T	T
Foxtail barley *(Hordeum jubatum)*	T	0%
Total	**19%**	**17%**
TOTAL	100%	100%

Diets were pooled across animal species and seasons.
T = Trace.

No differences were observed between summer and fall use of one-seed juniper, oak species, mountain mahogany, Apache plume, and ponderosa pine ($P > 0.05$). Skunkbush sumac was the only browse species to decline between summer and fall ($P < 0.05$). Summer and fall were the two seasons with the highest use of oak species and mountain mahogany. Between fall and winter, use of oak species declined ($P < 0.05$) and Apache plume and ponderosa pine use increased ($P < 0.05$). No differences were observed between the fall and winter use of one-seed juniper ($P > 0.05$) and the observed declines in mountain mahogany and Russian olive use were not significant ($P > 0.05$). Winter and spring use of one-seed juniper, oak species, mountain mahogany, Apache plume, and ponderosa pine were not significantly different ($P > 0.05$). Skunkbush sumac was the only browse species to decline ($P < 0.05$) between winter and spring. Winter and spring were the two seasons with the highest use of ponderosa pine. Use of big sagebrush (*Artemisia tridentata*) was only recorded during spring.

Overall seasonal use of forbs was not significantly different ($P > 0.05$) (Tables 3, C1 & C7). Use of mullein increased ($P < 0.05$) between summer and fall and fall and winter, with a decrease in use between winter and spring ($P < 0.05$). Mullein use was highest during the winter season. Scarlet globemallow use declined ($P < 0.05$) between fall and winter, and although there was an increase in use between winter and spring, the increase was not significant ($P > 0.05$). Use of purple prairie clover increased between fall and winter ($P < 0.05$) and, although there was a decline in use between winter and spring, the decline was not significant ($P > 0.05$).

Overall seasonal use of grasses was not significantly different ($P > 0.05$)(Tables 3, C1 & C7). There were also no differences in the seasonal use of slender wheatgrass and orchard grass ($P > 0.05$). Use of slender wheatgrass was highest during the winter season.

Table 3. Mean percent contribution of the primary forage species comparing seasons of the year.

Lifeform/species	Summer	Fall	Winter	Spring
Browse				
One-seed Juniper *(Juniperus monosperma)*	1.4%	2%	2.7%	5.3%
Oak species *(Quercus species)*	15%	17%	6.4%	9%
Mountain Mahogany *(Cercocarpus montanus)*	18%	13%	7.3%	4.4%
Apache plume *(Fallugia paradoxa)*	3%	T	6.6%	2%
Russian olive *(Elaeagnus angustifolia)*	10%	9%	3.3%	8.3%
Skunkbush sumac *(Rhus trilobata)*	10%	2%	3.7%	0%
Buckbrush *(Ceanothus fendlerii)*	0%	0%	0%	T
Pinon pine *(Pinus edulis)*	0%	T	0%	5%
Coyote willow *(Salix exigua)*	4%	0%	0%	0%
Douglas fir *(Pseudotsuga menziesii)*	2%	0%	0%	2%
Narrowleaf yucca *(Yucca angustissima)*	T	T	1.1%	T
Ponderosa pine *(Pinus ponderosa)*	3%	5%	13.4%	15%
Fourwing saltbush *(Atriplex canescens)*	T	4%	0%	0%
Rubber rabbitbrush *(Chrysothamnus nauseosus)*	0%	1%	1.5%	0%
Big sagebrush *(Artemisia tridentata)*	0%	0%	0%	4%
Total	**68%**	**53%**	**46%**	**55%**
Forbs				
Mullein *(Verbascum thapsus)*	2%	7%	15.6%	7.1%
Annual sunflower *(Helianthus annuus)*	4.2%	2%	1.5%	0%
White sweet clover *(Melilotus albus)*	2%	1%	1.7%	1%
Deer vetch *(Lotus wrightii)*	4%	1%	T	0%
Aster species *(Aster species)*	1%	0%	0%	0%
Scarlet globemallow *(Spaeralcea coccinea)*	6%	8%	1.6%	5%
Purple prairie clover *(Petalostemum purpureum)*	T	2%	6.9%	2.1%
Goldenrod species *(Solidago species)*	0%	T	0%	0%
Fringed sagebrush *(Artemisia frigida)*	0%	3%	0%	2.1%
Fleabane species *(Erigeron species)*	0%	0%	0%	4.3%
Tansy mustard *(Descurainia richardsonii)*	0%	0%	0%	2%
Bladderpod species *(Lesquerella species)*	0%	0%	0%	2.1%
Unid Forb species	2.1%	2%	1.4%	T
Total	**22%**	**26%**	**29%**	**26%**
Grasses				
Mutton grass *(Poa fendleriana)*	2%	4%	4.7%	3%
Canary reed grass *(Phalaris arundinacea)*	2%	4%	0%	1.1%
June grass *(Koelaria macrantha)*	2%	4%	2.2%	2%
Fescue species *(Festuca species)*	T	2%	4.5%	2%
Carex species *(Carex species)*	T	0%	T	0%
Slender wheatgrass *(Agropyron trachycaulum)*	T	3%	5.7%	3%
Longstyle rush *(Juncus longystylus)*	T	1%	0%	1.4%
Cheat grass *(Bromus tectorum)*	T	T	0%	T
Smooth brome *(Bromus inermis)*	T	1%	1.7%	1.6%
Blue grama grass *(Bouteloua gracilis)*	T	T	T	T
Orchard grass *(Dactylis glomerata)*	T	2%	2.9%	3%
Flatsedge species *(Cyperus species)*	0%	T	0%	0%
Little bluestem *(Schizachyrium scoparium)*	0%	T	1.2%	0%
Foxtail barley *(Hordeum jubatum)*	0%	0%	1.4%	0%
Total	**10%**	**21%**	**25%**	**19%**
TOTAL	100%	100%	100%	100%

Diets were pooled across animal species and years.
T = Trace.

Species X Season Effect

Elk (Within Species Comparisons)

The diets of elk, when pooled across years, revealed a ($P < 0.05$) decrease in the overall use of browse between summer and fall, no difference in use between fall and winter ($P > 0.05$), and an increase in browse use between winter and spring, but the increase was not significant ($P > 0.05$) (Tables 4, C2 & C8). The only seasonal difference in browse use by elk was the decline of skunkbush sumac ($P < 0.05$) between summer and fall.

Summer diets of elk consisted of 61% browse with oak species, mountain mahogany, coyote willow (*Salix exigua*), ponderosa pine, skunkbush sumac, and Douglas fir (*Pseudotsuga menziesii*) contributing greater than 5% of the diet (Table 4). During fall, elk diets consisted of 32% browse and only oak species, ponderosa pine, and four-wing saltbush (*Atriplex canescens*) contributed greater than 5% of the diet (Table 4). Winter diets of elk also consisted of 32% browse with ponderosa pine, Apache plume, and oak species contributing greater than 5% of the diet (Table 4). Spring diets of elk increased to 53% browse with ponderosa pine, oak species, big sagebrush, and Russian olive contributing greater than 5% percent of the diet (Table 4).

No significant differences in the overall seasonal use of forbs were observed in the diets of elk ($P > 0.05$) (Tables 4, C2 & C8). The only seasonal difference in use of forbs by elk was the increase of mullein ($P < 0.05$) between summer and fall. Use of mullein by elk was highest during winter and this forb species contributed greater than 5% of the diet during winter, fall, and spring (Table 4). Scarlet globemallow was the only other forb species to contribute greater than 5% of the diet, contributing greater than 5% of the diet during fall and spring (Table 4).

Table 4. Mean percent contribution of the primary forage species comparing animal species and seasons of the year.

	Summer		Fall		Winter		Spring	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Browse								
One-seed Juniper	2.7%	T	1.8%	2%	T	5.3%	1%	9.5%
Oak species	12.9%	17.2%	12%	22%	5.7%	7.3%	11.3%	6%
Mountain Mahogany	12%	23%	2.7%	24%	1.8%	12.8%	4.2%	4.7%
Apache plume	1.6%	4.2%	1%	0%	6.7%	6.4%	3%	2.5%
Russian olive	4.3%	15%	T	18%	2.8%	3.9%	7.4%	9%
Skunkbush sumac	5.8%	14.2%	0%	4%	1.2%	6.3%	0%	0%
Buckbrush	0%	0%	0%	0%	0%	0%	0%	T
Pinon pine	0%	0%	0%	T	0%	0%	T	9%
Coyote willow	9%	0%	0%	0%	0%	0%	0%	0%
Douglas fir	5.4%	0%	0%	0%	0%	0%	0%	4%
Narrowleaf yucca	T	0%	T	0%	2.2%	0%	1%	0%
Ponderosa pine	5.9%	T	8%	1%	8%	18.7%	16%	15%
Rubber rabbitbrush	0%	0%	0%	2%	3%	0%	0%	0%
Four-wing saltbush	T	0%	6%	5%	0%	0%	0%	0%
Big sagebrush	0%	0%	0%	0%	0%	0%	8%	0%
Total	**61%**	**74%**	**32%**	**78%**	**32%**	**61%**	**53%**	**60%**
Forbs								
Mullein	3.7%	T	11.8%	2%	14.5%	16.8%	7%	7%
Annual sunflower	1.8%	6.7%	3%	1%	2.5%	T	0%	0%
White sweet clover	2%	2.7%	T	2%	1.6%	1.7%	1%	1%
Deer vetch	3.6%	4.8%	0%	1%	T	0%	0%	0%
Aster species	T	T	0%	0%	0%	0%	0%	0%
Scarlet globemallow	3.4%	8.7%	5.9%	10%	3.2%	0%	5.3%	4.7%
Purple prairie clover	T	0%	2.6%	2%	4.3%	9.5%	0%	4.2%
Goldenrod species	0%	0%	T	0%	0%	0%	0%	0%
Fringed sagebrush	0%	0%	6%	T	0%	0%	0%	4.3%
Fleabane species	0%	0%	0%	0%	0%	0%	1%	7.7%
Tansy mustard	0%	0%	0%	0%	0%	0%	3.3%	0%
Bladderpod species	0%	0%	0%	0%	0%	0%	0%	4.2%
Unident. Forb species	2.9%	2.3%	1%	2%	1.7%	1%	1%	0%
Total	**19%**	**26%**	**31%**	**20%**	**29%**	**29%**	**19%**	**33%**
Grasses								
Mutton grass	4.5%	0%	7%	0%	9.4%	0%	6%	0%
Canaryreed grass	5.4%	0%	7%	0%	0%	0%	2.2%	0%
June grass	4.2%	0%	8%	0%	4.3%	0%	3%	0%
Fescue species	1.2%	0%	4%	0%	9%	0%	4%	0%
Carex species	T	0%	0%	0%	T	0%	0%	0%
Slender wheatgrass	T	0%	5%	1%	6.2%	5.3%	3%	2.5%
Longstyle rush	1.9%	0%	1%	0%	0%	0%	3%	0%
Cheatgrass	T	0%	T	0%	0%	0%	1.4%	0%
Smooth brome	T	T	1.6%	T	1.4%	2%	2.1%	1%
Blue grama grass	0%	T	T	0%	T	T	T	0%
Orchard grass	1.5%	0%	3%	1%	3.8%	2%	3%	3%
Flatsedge species	0%	0%	T	0%	0%	0%	0%	0%
Little bluestem	0%	0%	T	0%	2.3%	0%	0%	0%
Foxtail barley	0%	0%	0%	0%	2.7%	0%	0%	0%
Total	**20%**	**T**	**37%**	**2%**	**39%**	**10%**	**28%**	**7%**
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%

Diets were pooled across years.
T = Trace.

An increase in the overall use of grasses was observed in the diets of elk between summer and fall ($P < 0.05$) (Tables 4, C2 & C8). No differences in the overall use of grasses were observed between fall and winter and winter and spring ($P > 0.05$). Winter was the season with the highest overall use of grasses, with mutton grass, fescue species (*Festuca* species), and slender wheatgrass contributing greater than 5% of the diet (Table 4). Canaryreed grass (*Phalaris arundinacea*) was the only grass contributing greater than 5% of the summer diets of elk (Table 4). During fall, June grass, mutton grass, canaryreed grass, and slender wheatgrass contributed 5% or greater of the diet (Table 4). Mutton grass was the only grass contributing greater than 5% percent of the spring diets of elk (Table 4).

Mule Deer (Within Species Comparisons)

No significant differences were observed in the overall seasonal use of browse by mule deer ($P > 0.05$) (Tables 4, C3 & C9). Summer and fall were the two seasons with the highest overall use of browse. No differences were observed in the use of mountain mahogany, oak species, and Russian olive between summer and fall ($P > 0.05$). Use of skunkbush sumac decreased between summer and fall ($P < 0.05$). Between fall and winter use of mountain mahogany, oak species, and Russian olive also decreased ($P < 0.05$). Use of ponderosa pine increased substantially between fall and winter ($P < 0.05$). While between winter and spring use of skunkbush sumac decreased ($P < 0.05$).

Fall diets of mule deer consisted of 78% browse with mountain mahogany, oak species, Russian olive, and four-wing saltbush contributing 5% or greater of the diet (Table 4). During summer mule deer diets consisted of 74% browse with mountain mahogany, oak species, Russian olive, and skunkbush sumac contributing greater than 5% of the diet (Table 4). Winter diets of mule deer were made up of 61% browse with ponderosa pine, mountain mahogany, oak species, Apache plume, skunkbush sumac, and one-seed juniper contributing greater than 5% of the diet (Table 4). Spring diets of mule deer had 60% browse with ponderosa pine, one-seed juniper, Russian olive, piñon pine, and oak species contributing greater than 5% of the diet (Table 4).

No significant differences in the overall seasonal use of forbs were observed in the diets of mule deer ($P > 0.05$) (Tables 4, C3, & C9). One seasonal difference in the use of forbs by mule deer was the increase of mullein and purple prairie clover ($P < 0.05$) between fall and winter. Use of scarlet globemallow declined significantly between fall and winter ($P < 0.05$). Between winter and spring use of mullein and purple prairie clover also declined ($P < 0.05$).

No significant differences in the overall seasonal use of grasses were observed in the diets of mule deer ($P > 0.05$) (Tables 4, C3, & C9). Summer had only a trace of grasses, while during winter grasses made up 10% of mule deer diets (Table 4). Slender wheatgrass was the only grass species to contribute greater than 5% of mule deer diets (Table 4).

Elk vs. Mule Deer (Within Season Comparisons)

Browse

Within season comparisons of elk and mule deer diets revealed no significant differences in the overall use of browse during summer and spring ($P > 0.05$) and differences in browse use during fall and winter ($P < 0.05$) (Tables 4, C4, & C10). During fall and winter browse use was greater for mule deer than elk. No differences in the summer use of one-seed juniper, oak species, Apache plume, and Russian olive ($P > 0.05$) were observed between elk and mule deer diets. Summer use of oak species, Apache plume, and Russian olive, although not significant, was greater for mule deer than elk (Table 4).

During summer, differences in the use of mountain mahogany, skunkbush sumac, and ponderosa pine ($P < 0.05$) were observed between elk and mule deer diets. Use of mountain mahogany and skunkbush sumac was greater for mule deer than elk, while elk use of ponderosa pine was greater than mule deer use. I observed that elk use of mountain mahogany and skunkbush sumac was less selective and more destructive to the plant. Elk's inability to selectively browse led to increased consumption of thicker stemmed woody plant parts. Summer was the season with the highest overall use of browse by elk.

During fall the overall use of browse by elk was significantly lower than mule deer ($P < 0.05$) (Tables 4, C4 & C10). No differences in the fall use of one-seed juniper, oak species, Apache plume, and ponderosa pine ($P > 0.05$) were observed between elk and mule deer diets. Fall use of oak species, although not significant, was greater for mule deer than elk, while elk use of ponderosa pine was greater than mule deer use (Table 4). Use of mountain mahogany, Russian olive, and skunkbush sumac was greater for mule deer than elk during fall ($P < 0.05$). Fall was the season with the highest overall use of browse by mule deer.

During winter the overall use of browse by elk was also significantly lower than mule deer ($P < 0.05$) (Tables 4, C4, & C10). No differences in the winter use of oak species, Apache plume, and Russian olive ($P > 0.05$) were observed between elk and mule deer diets. A difference in the use of one-seed juniper, mountain mahogany, skunkbush sumac, and ponderosa pine ($P < 0.05$) was observed between elk and mule deer diets (Table 4). Compared to elk, use of one-seed juniper, mountain mahogany, skunkbush sumac, and ponderosa pine was greater for mule deer during winter ($P < 0.05$). Use of ponderosa pine by mule deer was highest during the winter season.

Overall use of browse by elk and mule deer during spring was not significantly different ($P > 0.05$) (Tables 4, C4 & C10). Use of skunkbush sumac was not recorded in either of the two diets ($P > 0.05$) and the only difference between diets was for the use of one-seed juniper ($P < 0.05$). During spring use of one-seed juniper was greater for mule deer than elk (Table 4). No differences were observed in the spring use of oak species, mountain mahogany, Apache plume, Russian olive, and ponderosa pine ($P > 0.05$). Elk use of oak species, although not significant, was greater than mule deer use during spring. Use of mountain mahogany, Apache plume, Russian olive, and ponderosa pine during spring revealed near to equal use of these browse species by elk and mule deer (Table 4).

Forbs

Within season comparisons of elk and mule deer diets revealed no significant differences in the overall seasonal use of forbs ($P > 0.05$) (Tables 4, C4 & C10). No differences in the summer use of mullein, annual sunflower, scarlet globemallow, and purple prairie clover ($P > 0.05$) were observed. Elk use of mullein during fall was greater than mule deer use ($P < 0.05$). No differences in the fall use of annual sunflower, scarlet globemallow, and purple prairie clover ($P > 0.05$) were observed between the diets of elk and mule deer. During winter no differences were also observed in the use of mullein, annual sunflower, and scarlet globemallow ($P > 0.05$). Use of purple prairie clover was greater ($P < 0.05$) for mule deer during winter (Table 4). Use of mullein by both elk and mule deer was highest during the winter season. No differences in the spring use of mullein, annual sunflower, scarlet globemallow, and purple prairie clover ($P > 0.05$) were observed between elk and mule deer diets.

Grasses

Within season comparisons of elk and mule deer diets revealed significant differences in the overall seasonal use of grasses ($P < 0.05$) (Tables 4, C4 & C10). No differences in the seasonal use of slender wheatgrass and orchard grass were observed ($P > 0.05$). Use of grasses by elk was greater ($P < 0.05$) than mule deer.

Seasonal Dietary Overlap

Seasonal dietary overlap was highest between elk and mule deer during summers 1998 (71.5%) and 1999 (70.2%). Dietary overlap was lowest during fall 1998 (51.4%) and spring 1999 (57.1%). All other seasons of the year had a calculated similarity index of greater than 50% (Table 5). Browse (trees/shrubs) and forb species contributed the highest percentages of dietary overlap in elk and mule deer diets on LANL during all seasons of the year except for winter 1999. Grass species contributed the lowest percentage of dietary overlap in elk and mule deer diets.

Table 5. Percent similarity of elk and mule deer diets comparing forage classes within seasons and years.

Forage	**Summer**		**Fall**		**Winter**		**Spring**	
Classes	**1998**	**1999**	**1998**	**1999**	**1998**	**1999**	**1999**	**2000**
Browse	28.6%	42.9%	19%	26.7%	22.2%	29.2%	23.8%	22.2%
Forbs	42.9%	27.3%	22.2%	28.6%	22.2%	13.3%	20%	24.2%
Grasses	0%	0%	10.4%	13.3%	20.5%	20%	13.3%	16.6%
Total	**71.5%**	**70.2%**	**51.4%**	**68.6%**	**64.9%**	**62.5%**	**57.1%**	**63%**

Dietary overlap between elk and mule deer diets on LANL was expected to be highest during winter as opposed to summer. For wild ruminants, such as elk and mule deer, winter is generally a period of nutritional deprivation resulting in the reduction of quantity and quality of available forage. Dormant winter plants are less digestible and contain less protein than summer forage (Short 1981, Wallmo and Regelin 1981), and deep snow may render large portions of forage supplies unavailable (Carpenter et al. 1979, Hobbs et al. 1981, Bartmann 1983, Mower and Smith 1989, Lindzey et al. 1997). On LANL, similarity of elk and mule deer diets was approximately 65% during winter 1998 and approximately 63% during winter 1999 (Table 5). Similarly, Mower and Smith (1989) found an overall diet similarity of 71% among common forage species in elk and mule deer winter diets in Utah. In that study elk and mule deer relied heavily on shrub species because the availability of forbs and grasses was reduced as a result of plant dormancy and snow cover.

At LANL, temperatures for winter 1998 were above normal during the month of December, and total monthly snowfall was below normal. During winter 1999, temperatures on LANL were above normal for January, February, and March. Total monthly snowfall during winter 1999 was also below normal. The lack of snow cover during winters 1998 and 1999 had a less profound effect on the availability of forbs and grasses. During winters 1998 and 1999 elk and mule deer on LANL had more access to forbs and grasses, which was reflected in their diets and high diet similarity, and therefore did not have to rely as heavily on shrub species.

The plant growing season, or summer, is generally a period of good quality forage for ruminants such as elk and mule deer (Short et al. 1977, Wallmo and Regelin 1981). During this season of rapid plant growth and active photosynthesis, vegetation is high in protein and low in fiber content (Short 1981, Hanley 1982). At LANL, similarity of elk and mule deer diets was approximately 72% during summer 1998 and 70% during summer 1999. These findings are similar to what has been previously reported in the literature. In southern Colorado, Hansen and Reid (1975) found that during summer the overall diet similarity of elk and mule deer food habits was higher than that of any other season. In Montana, Mackie (1970) also found that the food habits of elk and mule deer were more similar during the growing season and less similar at other times of the year. More recently in south-central New Mexico, Tafoya (2000) found that diet similarity of elk and mule deer diets was greatest (81%)

during the warm/wet season (July through November).

Although this study and the study in south-central New Mexico are not exactly the same, the results are somewhat similar. In south-central New Mexico, Tafoya (2000) found that during the warm/wet season diets of mule deer consisted of 53.2% browse, 39.1% forbs, and 7.7% grasses and that elk diets consisted of 48.7% browse, 40.8% forbs, and 10.5% grasses. At LANL during summers 1998 and 1999, browse and forbs also contributed the greatest percentages of elk and mule deer diets.

Another interesting similarity between this study and the study in south-central New Mexico was that during the peak rainfall month of August on LANL, precipitation was below normal for both summers in 1998 and 1999. During the study in south-central New Mexico, Tafoya (2000) reported that only 17.8% of that year's precipitation fell before July 1 and the long- term average of precipitation falling before July 1 was approximately 33%. Mangold (1997) suggested that forage availability is dependent upon weather conditions. Tafoya (2000) concluded that below-normal precipitation before the warm/wet season could have had an effect on the availability and vigor of forbs and grasses, which in turn may have influenced the increased use of browse by elk and mule deer. A similar effect may have taken place on LANL during the summers of 1998 and 1999.

Plant species and plant parts differ in their proportions of cellular contents and plant cell walls. Cellular contents are generally 98% digestible and found in high proportions in the thin cell walls of rapidly growing plant tissues and the leaves and new stem production of shrubs and forbs (Short 1981, Hanley 1982). Plant cell walls are composed primarily of cellulose, which can be digested by rumen microbes; hemicellulose that may or may not be digestible; and lignin that is considered nondigestible (Smith et al. 1971, 1972). Mature grasses and woody tissue generally have thick cell walls, composed primarily of cellulose in grasses, and relatively high in lignin in shrubs (Short 1971, 1981). Plant cellular contents are the most valuable food source for herbivores, but their availability is seasonal and depends on the degree of selectivity an herbivore can exercise (Hanley 1982). Cellulose, which is abundant in grasses during all growth stages, is also a potentially high-energy food source for herbivores (Smith et al. 1971, 1972).

Elk are considered primarily grazers because they have a larger rumen, which allows for increased retention time and digestion of high-cellulose diets (Short et al. 1965, Church and Hines 1978, Short 1978, Hanley 1982, Baker and Hansen 1985, Baker and Hobbs 1987). Mule deer, on the other hand, have a relatively small rumen and shorter retention time and are considered less adapted for digestion of grasses (Short et al. 1965, Wallmo et al. 1977, Short 1981, Hanley 1982, Baker and Hansen 1985). Instead, mule deer are considered primarily browsers because a smaller rumen and shorter retention time allows for very rapid digestion of plant cellular contents and rapid passage of lignified cell walls (Short et al. 1965, Short 1981, Hanley 1982, Baker and Hobbs 1987). On Bandelier National Monument adjacent to LANL, Potter and Berger (1977) found that in ponderosa pine and piñon-juniper habitat type's browse constituted greater than 90% of mule deer diets.

Compared to elk, mule deer have smaller mouth parts, which allows this species to selectively browse leaves and current annual growth of shrubs and forbs (Blair et al. 1977, Short 1977, Short 1981, Hanley 1982). Hobbs et al. (1983) documented that plant parts eaten by mule deer were more digestible and had twice the crude protein levels of plant parts eaten by elk. Elk are capable of thriving on relatively lower-quality forage (a predominantly grass diet), while mule deer require higher-quality forages (a mixed diet of shrubs and forbs) to meet their metabolic needs (Hanley 1982, Bartmann 1983, Lindzey et al. 1997). Studies show that use of grasses by mule deer is heaviest during spring when succulent new growth is available (Smith 1952, Kufeld et al. 1973, Carpenter et al. 1979, Hanley 1982).

Mule deer requiring higher-quality forage to meet their metabolic needs is the most logical reason why shrubs and forbs dominated the seasonal diets of mule deer on LANL. Use of grasses by mule deer on LANL was highest during spring and winter. Spring use of grasses by mule deer was during the period of succulent new growth when grasses had thinner cell walls and higher cellular contents, which is consistent with studies previously described. However, use of grasses by mule deer during winter at LANL, may have been more so a result of increased availability of grasses due to below normal snowfall and above normal temperatures. On piñon-juniper mule deer winter range in Colorado, Bartmann (1983) found that on south exposures with shallower snow depth, use by mule deer of available forbs and grasses increased in November. Wallmo and Regelin (1981) and Rowland et al. (1983) also noted that digestibility of grasses during winter is high compared to shrubs because grasses have lower levels of lignin. This may have also influenced mule deer use of grasses during winter at LANL.

Kufeld (1973) and Bubenik (1982) noted that elk are extraordinarily adaptable ruminants that can consume mixed diets of grass, forbs, and browse, yet show a clear preference for diets dominated by grass and, to a lesser extent, forbs. Elk are considered year-round grazers with slight increases in browse during winter months when grasses and forbs become less available and nutritive quality decreases (Hobbs et al. 1981, Baker and Hobbs 1987, Nelson and Leege 1982). In the Jemez Mountains of New Mexico, Rowland et al. (1983) found that winter diets of elk consisted of approximately 90% grasses. On montane meadows in Bandelier National Monument, Wolters (1993) found that on a seasonal basis elk consumed greater proportions of forbs followed by the consumption of grasses and browse.

Lang (1958) found 77% use of shrubs, 21% grasses, and 2% forbs in the fall diets of elk in New Mexico. In modified piñon-juniper woodlands, Short et al. (1977) found that elk diets consisted of 74% trees/shrubs during the fall/winter and 71% during the spring/summer. Hobbs et al. (1983) and Collins and Urness (1983) pointed out that mule deer consumed more browse than elk and elk more grass than mule deer, but browse consumption by elk increased in winter. Mower and Smith (1989) also observed that wintering elk in Utah relied heavily on shrub species.

On LANL, browse dominated the spring/summer diets of elk. According to Nelson and Leege (1982), food habits of elk are extremely variable depending on where in the United States they are found and what type of forage is available.

Because of below-normal precipitation during our study period, availability of grasses and forbs may have been less than in previous years during spring/summer, resulting in an increased consumption of browse by elk on LANL. This conclusion agrees with the findings of other food habit studies conducted on elk where drought had an effect on forage availability (Short et al. 1977, Mangold 1997, Tafoya 2000).

Russian olive is a shrub species introduced from Asia into the United States because it formed excellent windbreaks (Carter 1997). This introduced shrub can withstand drought and cold winters, spreads rapidly, and is difficult to control. Mullein is another introduced forb species from the Mediterranean region commonly found in disturbed areas (Potter and Berger 1977, Foxx and Hoard 1995). A review of the literature found no mention of Russian olive and mullein being important forage species in elk and mule deer diets (Lang 1957, 1958, Kufeld 1973, Kufeld et al. 1973, Potter and Berger 1977, Short et al. 1977, Wallmo and Regelin 1981, Nelson and Leege 1982, Rowland et al. 1983, Wolters 1993, Joseph 1995, Mangold 1997, Tafoya 2000). A competition study on mule deer and burros conducted by Potter and Berger (1977) at Bandelier National Monument adjacent to LANL found that slightly more than 1% of mule deer diets in spring consisted of mullein and only a trace during winter.

On LANL both Russian olive and mullein were found in the diets of elk and mule deer during each season of the two-year study period. In the diets of elk, Russian olive contributed 5% or greater of elk diets during summer 1999, winter 1999, and spring 2000 (Tables D1 & D2). Mullein contributed 5% or greater of elk diets during summer 1998, fall 1998 and 1999, winter 1998 and 1999, and spring 1999 and 2000 (Tables D1 & D2). Russian olive in the diets of mule deer contributed 5% or greater of the diet during summer 1998 and 1999, fall 1998 and 1999, and spring 2000 (Tables D1 & D2). Mullein contributed 5% or greater of mule deer diets during winter 1998 and 1999 and spring 1999 and 2000 (Tables D1 & D2).

Geist (1982) noted that elk are opportunistic and will take advantage of locally abundant food sources brought about by ecological and climatic factors. Anthony (1976) found that in Arizona during drought conditions mule deer consumed more drought-resistant forage plants instead of more highly preferred deciduous species. Russian olive's ability to withstand drought and cold winters may have increased its availability and use by elk and mule deer on LANL. Use of mullein by elk and mule deer on LANL may have also been related to the ability of this introduced forb to thrive in dryer than normal growing conditions.

Field observations by the author confirmed that elk and mule deer were consuming mature ponderosa pine needles. This observation was further verified upon fecal analysis of elk and mule deer seasonal diets within the study area. Within species comparisons revealed that elk use of ponderosa pine was highest during summer and fall, while mule deer use of ponderosa pine was highest during winter.

Lang (1958) mentioned finding traces of pine species in the stomach contents of seven elk killed in the Gila National Forest during December 1952. In a review of the literature of the most frequently cited forages of Rocky Mountain mule deer Kufeld et al. (1973) found that ponderosa pine was cited 32 times. A review of pertinent literature found no mention of ponderosa pine playing an important role in the diets of elk and mule deer (Lang 1957, Kufeld 1973, Potter and Berger 1977, Short et al. 1977, Wallmo and Regelin 1981, Nelson and Leege 1982, Rowland et al. 1983, Wolters 1993, Joseph 1995, Mangold 1997, Tafoya 2000). Increased use of ponderosa pine by elk and mule deer on LANL, especially elk use, may have been the result of below-normal precipitation and above-normal temperatures during the two-year study that may have led to poor range conditions and reduced plant productivity.

Possible Biases Associated with Fecal Analysis

Estimating botanical composition of the diets of large herbivores such as elk and mule deer using fecal analysis may be biased by several factors. One such factor is the differences in digestion rates of various plant species (Anthony and Smith 1974, Dearden et al. 1975, Vavra et al. 1978, Holechek et al. 1982). The rate of digestion of a plant species depends on the plant form and the growth stage of the plant (Mohammad et al. 1995). Herbaceous species such as forbs are likely to be digested more thoroughly than woody species (Smith 1952). Because of this, fecal analysis may be biased toward tree and shrub species (Anthony and Smith 1974, Wolters 1993). Several studies have reported that grasses were often overestimated and forbs were underestimated because the resistance of grasses to digestion was greater than that of forbs (Havstad and Donart 1978, Vavra et al. 1978, Vavra and Holechek 1980, McInnis et al. 1983, Bartolome et al. 1995).

Some forage species also may become unidentifiable after passing through the digestive tract and therefore may be misrepresented in the diet (Slater and Jones 1971, Smith and Shanduk 1979). Other species with dense stellate hairs or trichomes may be overestimated (Sanders et al. 1980). Large plant fragments in the feces also may cause misrepresentation of a species. The frequency of the species may be low, but because of the size of the fragments, the species may contribute more to the estimate than many other plant fragments (Storr 1961). Species may also be differentially fragmented so that the proportion of the plant consumed does not equal the proportion of the fragments observed in the feces (Owen 1975, Holechek et al. 1982).

Observer error and training (Holechek and Gross 1982b, Holechek et al. 1982, Alipayo et al. 1992, Bartolome et al. 1995), sample preparation (Vavra and Holechek 1980, Holechek 1982), calculation procedures for analysis (Holechek and Gross 1982a), microscope magnification levels (Holechek and Valdez 1985), presence of woody material (Holechek and Valdez 1985), and sample size (Anthony and Smith 1974) are other factors that may cause biases. Because of these biases, food habits results of this and other studies should be interpreted with caution.

Despite these limitations, fecal analysis has become a widely used technique for studying the diets of large herbivores such as elk and mule deer. This technique allows for practically unlimited sampling (Anthony and Smith 1974). Sampling can also be done when animals are being sacrificed and utilization techniques are not practical (Johnson and Person 1981). Fecal analysis involves no interference of the normal behavior of animals, it can also be used where several herbivores occupy the same range, and it is the only feasible procedure to use for studying rare, endangered, or secretive animals (Anthony and Smith 1974, Vavra et al. 1978).

MANAGEMENT RECOMMENDATIONS

Results of this study revealed the high use of browse by elk on LANL. Browse dominated the spring/summer diets of elk. According to Wallmo and Regelin (1981), browse is of greatest importance to mule deer during the green-leaf stage, or summer. Cliff (1939) and Nelson (1982) noted that when forage was a limiting factor, mule deer could not successfully compete with elk because elk could browse higher than mule deer. Collins and Urness (1983) stated that there was considerable potential for exploitative competition between mule deer and elk in favor of elk. Lindzey et al. (1997) also pointed out that elk will likely fair relatively better feeding on seasonally preferred mule deer foods than mule deer on those foods preferred by elk. Mangold (1997) stated that if the consumption of key forage species by elk is detrimental to mule deer populations, then elk populations need to be reduced.

The results of this study show that the potential for seasonal dietary overlap of forage species between elk and mule deer exists and is high during periods of drought. Holechek et al. (1998) noted that if animals using the same range share one or more of the same key forage species and have a dietary overlap between 30% to 70%, grazing by these animals is non-additive. Howard et al. (1990) conducted a common use study on cattle, sheep, and pronghorn (*Antilocapra americana*) and found that dietary overlap between sheep and pronghorn averaged 45%, increasing to 60% during drought. During the same study, dietary overlap between cattle and sheep was 18%, increased to 30% during drought, and grazing by these animals was additive. On pastures used by cattle and pronghorn, pronghorn survived well during drought. On pastures used by sheep and pronghorn, sheep depleted forbs during drought then shifted their consumption to grasses. After depletion of forbs by sheep, pronghorn perished because they require a high forb and shrub diet throughout the year and shrubs were in low supply within that study area.

Common use of forage species by elk and mule deer in this study is non-additive because seasonal dietary overlap was between 50% to 70% and elk and mule deer shared more than one key forage species. Depletion of forbs and shrubs by elk during drought may result in a reduction of mule deer numbers because, like pronghorn, mule deer require a high forb and shrub diet throughout the year due to a small digestive system relative to body weight. Since the 1940s, hunting has not been allowed within the boundaries of LANL; therefore, increased hunting pressure to reduce elk numbers on adjacent USFS property and pueblo land may be necessary.

Land changes that will affect elk and mule deer populations in the future have occurred on LANL and adjacent USFS property following the Cerro Grande fire of 2000. Immediately following the fire, aerial seeding of moderate and high-burn severity areas occurred to provide temporary ground cover and decrease the potential for erosion. A seed mix of annual ryegrass (*Lolium multiflorum*), barley (*Hordeum vulgare*), mountain brome (*Bromus marginatus*), and slender wheatgrass was used to seed approximately 372 hectares on LANL and 5,434 hectares on adjacent USFS property (Ecology Group 2001).

Existing-high density tree stands and the potential future risks of catastrophic wildfires at LANL also led to the thinning of approximately 4,047 hectares of forest surrounding buildings, structures, utilities, and low-severity burn areas (Ecology Group 2001). Ponderosa pine and piñon-juniper woodlands cover most of LANL and the majority of thinning has been focused in these two habitat types.

Re-seeded areas on LANL and adjacent USFS property have the potential of providing populations of elk with excellent wintering habitat. Following the La Mesa fire in 1977, White (1981) predicted that use of additional wintering habitat created during that fire by elk would lead to future problems with overpopulation of elk herds in the area. Response of elk populations to the most recent re-seeding is yet to be determined.

Thinning efforts on LANL have the potential of enhancing the generation of more favorable shrub, forb, and grass species, which will benefit both elk and mule deer. One concern with the thinning of areas surrounding buildings, structures, and utilities is the potential of attracting elk and mule deer closer to major road ways. In the future this may lead to increases in elk and mule deer vehicle-related accidents. Additional research needs to be conducted to monitor the responses of elk and mule deer populations at LANL to these land changes.

APPENDICES

APPENDIX A: MAPS

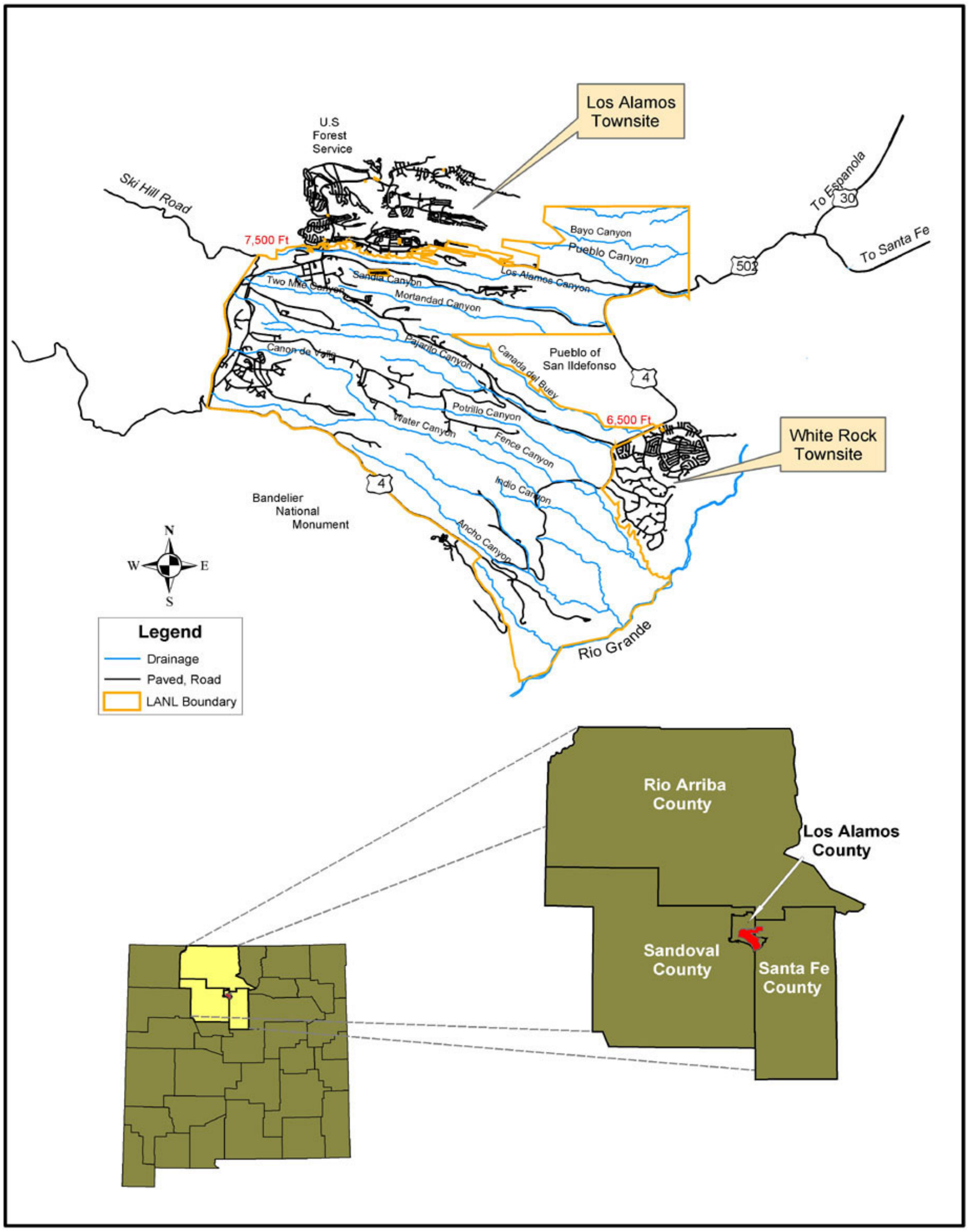

Figure A1. Los Alamos National Laboratory.

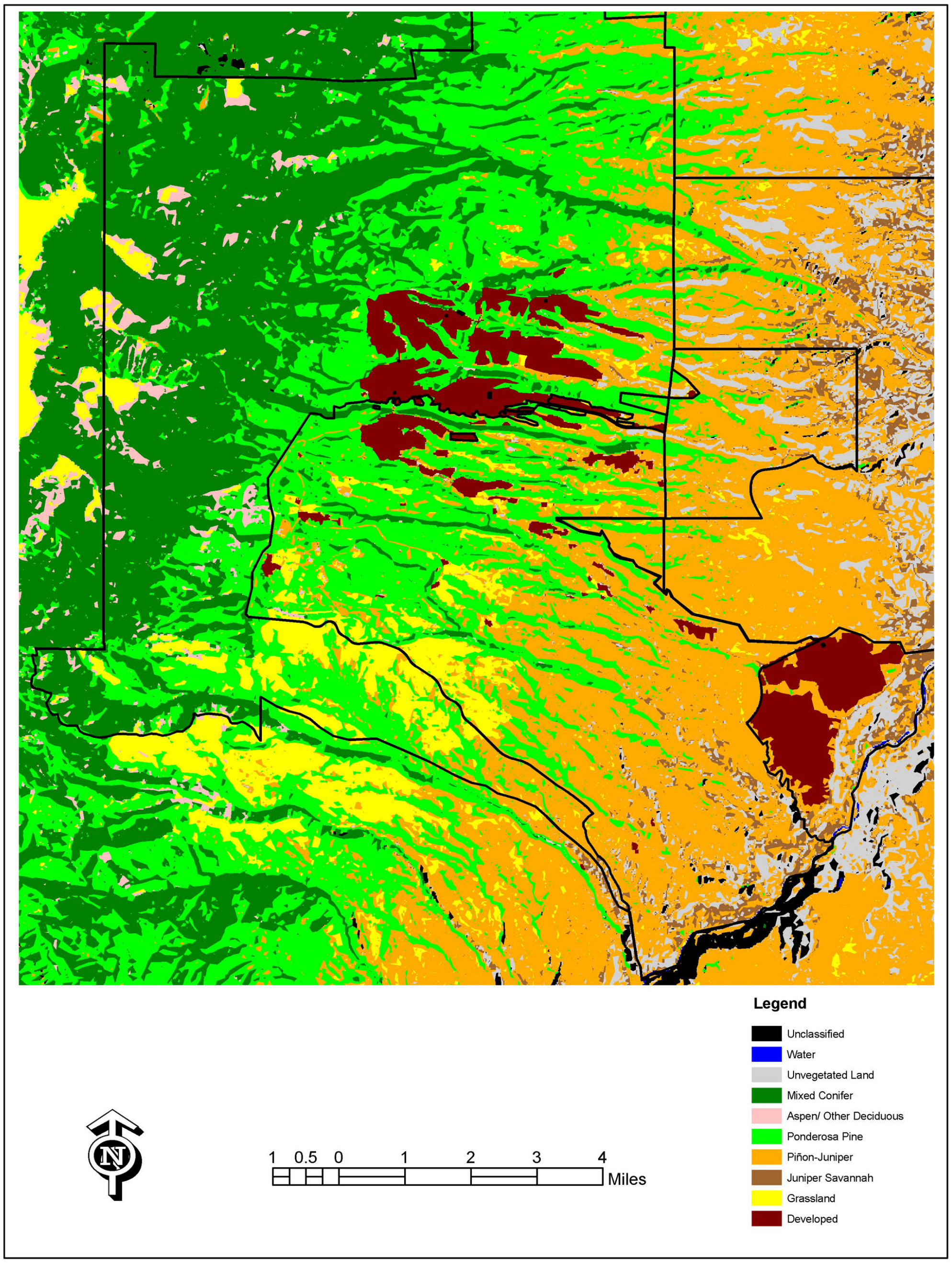

Figure A2. Land Cover Types at Los Alamos National Laboratory (Koch et al. 1997).

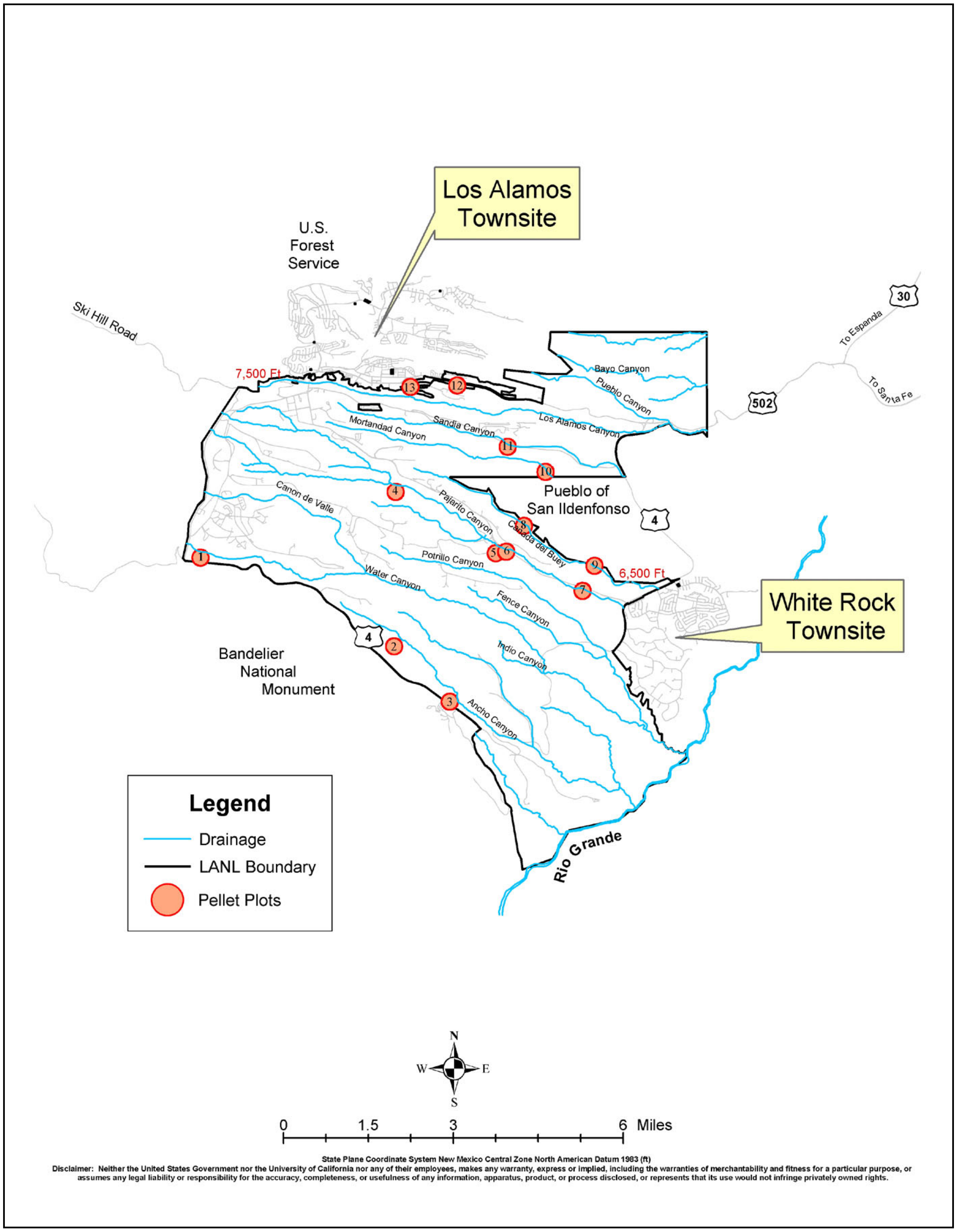

Figure A3. Pellet plot locations at Los Alamos National Laboratory.

APPENDIX B: SAMPLE NUMBERS

Table B1. Sample numbers by plot and season for elk and mule deer at Los Alamos National Laboratory during year 1.

Season	Summer 1998		Fall 1998		Winter 1998		Spring 1999	
Plot #	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
1	**14**	**11**	**19**	0	**44**	1	0	0
2	1	0	0	**6**	11	**5**	**3**	**4**
3	0	0	6	1	3	0	0	0
4	**5**	1	0	1	**18**	**2**	0	0
5	0	0	0	0	1	0	3	0
6	4	1	**8**	0	13	0	11	0
7	**8**	0	**7**	0	15	0	3	0
8	0	0	2	0	7	0	1	0
9	1	0	0	0	8	0	**5**	0
10	0	0	0	0	1	0	0	0
11	3	0	0	0	**18**	0	**6**	0
12	0	**16**	0	**16**	1	**3**	5	**7**
13	0	**4**	0	**4**	0	3	10	0

Each sample represents a set of five pellets.

Pellet samples in bold text were used during microhistological analysis.

Table B2. Sample numbers by plot and season for elk and mule deer at Los Alamos National Laboratory during year 2.

Season	Summer 1999		Fall 1999		Winter 1999		Spring 2000	
Plot #	**Elk**	**Mule Deer**	**Elk**	**Mule Deer**	**Elk**	**Mule Deer**	**Elk**	**Mule Deer**
1	0	0	0	0	9	0	**5**	**3**
2	0	**3**	**5**	3	**5**	**6**	0	2
3	3	**3**	4	**4**	4	2	0	0
4	0	0	2	0	4	0	0	0
5	0	0	2	0	**6**	0	2	0
6	**4**	0	**13**	0	18	1	**6**	3
7	**3**	0	**14**	0	8	0	2	0
8	0	0	0	0	3	0	0	0
9	0	0	0	0	3	0	0	0
10	0	0	0	0	3	0	0	0
11	0	0	1	0	4	0	0	0
12	0	0	0	**3**	0	**15**	1	**12**
13	**10**	**5**	6	**2**	**3**	**4**	**3**	**7**

Each sample represents a set of five pellets.
Pellet samples in bold text were used during microhistological analysis.

APPENDIX C: ANOVA SUMMARIES

Table C1. ANOVA summary (P-values) of the species, year, and season comparisons of elk and mule deer diets at Los Alamos National Laboratory.

Lifeform/species	**Species**	**Year**	**Season**
Browse	***0.0001**	0.2206	**0.0471**
Forbs	0.3415	0.4149	0.4488
Grasses	***0.0001**	0.4488	0.1520
One-seed Juniper	**0.0106**	0.8777	0.0715
Oak species	0.2947	0.3145	**0.0130**
Mountain Mahogany	**0.0003**	0.1151	**0.0073**
Apache plume	0.8942	0.1988	0.1482
Russian olive	**0.0252**	0.5191	0.4941
Skunkbush sumac	**0.0004**	**0.0037**	***0.0001**
Ponderosa pine	0.7893	0.9159	**0.0027**
Mullein	0.1578	0.7524	***0.0001**
Scarlet globemallow	0.5176	**0.0169**	0.2015
Purple prairie clover	0.0580	0.3778	**0.0008**
Slender wheatgrass	0.3089	0.7558	0.0637
Orchard grass	0.2024	0.1563	0.2728

An asterisk (*) next to a P-value means less than.

Table C2. ANOVA summary (P-values) of the species X season comparisons of elk diets at Los Alamos National Laboratory (Within Species Comparisons).

Lifeform/species	**Summer vs. Fall**	**Summer vs. Winter**	**Summer vs. Spring**
One-seed Juniper *(Juniperus monosprema)*	0.6671	0.2263	0.3649
Oak species (Qu*ercus* species*)*	0.9220	0.7460	0.1561
Mountain Mahogany *(Cercocarpus montanus)*	0.0887	0.0635	0.1481
Apache plume *(Fallugia paradoxa)*	0.9147	0.1731	0.8341
Russian olive *(Elaeagnus angustifolia)*	0.5727	0.8077	0.6540
Skunkbush sumac *(Rhus trilobata)*	**0.0154**	**0.0493**	**0.0154**
Ponderosa pine *(Pinus ponderosa)*	0.6708	0.7377	0.0566
Browse	**0.0047**	**0.0082**	0.3366
Mullein *(Verbascum thapsus)*	**0.0190**	**0.0027**	0.3522
Annual sunflower *(Helianthus annuus)*	0.6683	0.8863	0.5855
Scarlet globemallow *(Spharalcea coccinea)*	0.5456	0.9623	0.6485
Purple prairie clover *(Petalostemum purpureum)*	0.3560	0.0692	0.8163
Forbs	0.0694	0.1830	0.9224
Slender wheatgrass *(Agropyron trachycaulum)*	0.0965	**0.0483**	0.3997
Orchard grass *(Dactylis glomerata)*	0.3473	0.1801	0.5155
Grasses	**0.0464**	**0.0341**	0.2226

Table C2 Continued. ANOVA summary (P-values) of the species X season comparisons of elk diets at Los Alamos National Laboratory (Within Species Comparisons).

Lifeform/species	**Fall vs. Winter**	**Winter vs. Spring**
One-seed Juniper *(Juniperus monosprema)*	0.4296	0.7548
Oak species (Que*rcus* species*)*	0.1853	0.2685
Mountain Mahogany *(Cercocarpus montanus)*	0.8683	0.6617
Apache plume *(Fallugia paradoxa)*	0.1431	0.2457
Russian olive *(Elaeagnus angustifolia)*	0.7476	0.4904
Skunkbush sumac *(Rhus trilobata)*	0.6088	0.6088
Ponderosa pine *(Pinus ponderosa)*	0.9279	0.1107
Browse	0.8249	0.0740
Mullein *(Verbascum thapsus)*	0.4396	**0.0275**
Annual sunflower *(Helianthus annuus)*	0.7750	0.4921
Scarlet globemallow *(Spharalcea coccinea)*	0.5150	0.6151
Purple prairie clover *(Petalostemum purpureum)*	0.3519	**0.0424**
Forbs	0.6076	0.1543
Slender wheatgrass *(Agropyron trachycaulum)*	0.7350	0.2386
Orchard grass *(Dactylis glomerata)*	0.6796	0.4809
Grasses	0.8810	0.3385

Table C3. ANOVA summary (P-values) of the species X season comparisons of mule deer diets at Los Alamos National Laboratory (Within Species Comparisons).

Lifeform/species	**Summer vs. Fall**	**Summer vs. Winter**	**Summer vs. Spring**
One-seed Juniper *(Juniperus monosprema)*	0.3827	**0.0131**	**0.0001**
Oak species *(Quercus* species)	0.3214	0.0530	**0.0432**
Mountain Mahogany *(Cercocarpus montanus)*	0.8511	0.0603	**0.0025**
Apache plume *(Fallugia paradoxa)*	0.2532	0.5278	0.6643
Russian Olive *(Elaeagnus angustifolia)*	0.6540	0.0971	0.4106
Skunkbush sumac *(Rhus trilobata)*	**0.0002**	**0.0016**	***0.0001**
Ponderosa pine *(Pinus ponderosa)*	0.8881	**0.0008**	**0.0083**
Browse	0.8989	0.2129	0.2272
Mullein *(Verbascum thapsus)*	0.4455	***0.0001**	**0.0496**
Annual sunflower *(Helianthus annuus)*	0.1205	0.0626	0.0625
Scarlet globemallow *(Spharalcea coccinea)*	0.7293	**0.0488**	0.3801
Purple prairie clover *(Petalostemum purpureum)*	0.3205	***0.0001**	0.0642
Forbs	0.6606	0.6203	0.3278
Slender wheatgrass *(Agropyron trachycaulum)*	0.6990	0.0624	0.4519
Orchard grass *(Dactylis glomerata)*	0.6012	0.2748	0.0913
Grasses	0.8301	0.2957	0.5222

An asterisk (*) next to a P-value means less than.

Table C3 Continued. ANOVA summary (P-values) of the species X season comparisons of mule deer diets at Los Alamos National Laboratory (Within Species Comparisons).

Lifeform/species	**Fall vs. Winter**	**Winter vs. Spring**
One-seed Juniper *(Juniperus monosprema)*	0.0908	0.0643
Oak species *(Quercus* species)	**0.0050**	0.8336
Mountain Mahogany *(Cercocarpus montanus)*	**0.0404**	0.1578
Apache plume *(Fallugia paradoxa)*	0.0811	0.3063
Russian Olive *(Elaeagnus angustifolia)*	**0.0384**	0.4421
Skunkbush sumac *(Rhus trilobata)*	0.4836	**0.0127**
Ponderosa pine *(Pinus ponderosa)*	**0.0012**	0.5065
Browse	0.1714	0.9740
Mullein *(Verbascum thapsus)*	**0.0002**	**0.0109**
Annual sunflower *(Helianthus annuus)*	0.7401	0.9118
Scarlet globemallow *(Spharalcea coccinea)*	**0.0226**	0.3047
Purple prairie clover *(Petalostemum purpureum)*	**0.0016**	**0.0283**
Forbs	0.3526	0.6050
Slender wheatgrass *(Agropyron trachycaulum)*	0.1330	0.2969
Orchard grass *(Dactylis glomerata)*	0.5636	0.4926
Grasses	0.4034	0.7247

Table C4. ANOVA summary (P-values) of the species X season comparisons of elk and mule deer diets at Los Alamos National Laboratory (Within Season Comparisons).

Lifeform/species	**Summer**	**Fall**	**Winter**	**Spring**
One-seed Juniper	0.1994	0.9933	**0.0158**	**0.0003**
Oak species	0.3847	0.0557	0.7486	0.3399
Mountain Mahogany	**0.0438**	**0.0003**	**0.0462**	0.9259
Apache plume	0.4952	0.7167	0.9480	0.9895
Russian olive	0.1113	**0.0122**	0.8631	0.4823
Skunkbush sumac	**0.0008**	**0.0442**	**0.0290**	1.0000
Ponderosa pine	0.2553	0.1582	**0.0349**	0.8894
Browse	0.2324	**0.0001**	**0.0093**	0.4091
Mullein	0.2970	**0.0096**	0.4756	0.8799
Annual sunflower	0.1441	0.5996	0.5682	1.0000
Scarlet globemallow	0.2207	0.3308	0.4566	0.8849
Purple prairie clover	0.8163	0.8727	**0.0248**	0.0642
Forbs	0.3257	0.1947	0.8918	0.0512
Slender wheatgrass	0.8798	0.1500	0.7856	0.8530
Orchard grass	0.4369	0.2340	0.3032	0.7065
Grasses	**0.0321**	**0.0003**	**0.0019**	**0.0128**

Table C5. ANOVA summary of the overall diets of elk and mule deer pooled across seasons and years at Los Alamos National Laboratory (Species Effect).

Lifeform/Species	Elk	Mule Deer
One-seed Juniper *(Juniperus monosperma)*	1.5**a**	4.2**b**
Oak species *(Quercus* species)	11a	13a
Mountain Mahogany *(Cercocarpus montanus)*	5.2**a**	16.1**b**
Apache plume *(Fallugia paradoxa)*	3.1a	3.2a
Russian olive *(Elaeagnus angustifolia)*	3.8**a**	11.5**b**
Skunkbush sumac *(Rhus trilobata)*	1.7**a**	6.3**b**
Ponderosa pine *(Pinus ponderosa)*	9.4a	8.7a
Browse	**44a**	**67b**
Mullein *(Verbascum thapsus)*	9.2a	6.8a
Annual sunflower *(Helianthus annuus)*	1.9a	2.1a
Scarlet globemallow *(Spaeralcea coccinea)*	4.4a	6a
Purple prairie clover *(Petalostemum purpureum)*	2a	4a
Forbs	**25a**	**28a**
Slender wheatgrass *(Agropyron trachycaulum)*	4a	2.2a
Orchard grass *(Dactylis glomerata)*	2.8a	1.5a
Grasses	**31a**	**5b**

a, b; Means with different lower case letters within the same row are significantly different at $P < 0.05$.

Table C6. Year ANOVA summary of the overall diets of elk and mule deer pooled across animal species and seasons at Los Alamos National Laboratory (Year Effect).

Lifeform/species	**Year 1**	**Year 2**
One-seed Juniper (*Juniperus monosperma*)	3a	2.9a
Oak species (*Quercus* species)	10.6a	13.1a
Mountain Mahogany (*Cercocarpus montanus*)	8.5a	12.8a
Apache plume (*Fallugia paradoxa*)	4.3a	1.9a
Russian olive (*Elaeagnus angustifolia*)	6.6a	8.7a
Skunkbush sumac (*Rhus trilobata*)	2.2**a**	5.8**b**
Ponderosa pine (*Pinus ponderosa*)	9.3a	8.9a
Browse	**53a**	**59a**
Mullein (*Verbascum thapsus*)	7.7a	8.3a
Annual sunflower (*Helianthus annuus*)	2.4a	1.6a
Scarlet globemallow (*Spaeralcea coccinea*)	2.5**a**	8**b**
Purple prairie clover (*Petalostemum purpureum*)	3.3a	2.5a
Forbs	**28a**	**24a**
Slender wheatgrass (*Agropyron trachycaulum*)	2.7a	3a
Orchard grass (*Dactylis glomerata*)	3a	1.5a
Grasses	**19a**	**17a**

a, b; Means with different lower case letters within the same row are significanlty different at P < 0.05.

Table C7. ANOVA summary of the overall diets of elk and mule deer pooled across animal species and years at Los Alamos National Laboratory (Season Effect).

Lifeform/species	**Summer**	**Fall**	**Winter**	**Spring**
One-seed Juniper *(Juniperus monosperma)*	1.4a	2a	2.7ab	5.3b
Oak species *(Quercus* species*)*	15a	17a	6.4b	9ab
Mtn Mahogany *(Cercocarpus montanus)*	18a	13ab	7.3b	4.4b
Apache plume *(Fallugia paradoxa)*	3a	0.7a	6.6ab	2a
Russian olive *(Elaeagnus angustifolia)*	10a	9a	3.3a	8.3a
Skunkbush sumac *(Rhus trilobata)*	10a	2b	3.7b	0c
Ponderosa pine *(Pinus ponderosa)*	3a	5a	13b	15b
Browse	**68a**	**53b**	**46b**	**55ab**
Mullein *(Verbascum thapsus)*	2a	7b	15.6c	7.1d
Annual sunflower *(Helianthus annuus)*	4.2a	2a	1.5a	0a
Scarlet globemallow *(Spaeralcea coccinea)*	6a	8a	1.6ab	5a
Purple prairie clover *(Petalostemum purpureum)*	0.2a	2a	6.9b	2.1a
Forbs	**22a**	**26a**	**29a**	**26a**
Slender wheatgrass *(Agropyron trachycaulum)*	0.2a	3ab	5.7b	3ab
Orchard grass *(Dactylis glomerata)*	0.7a	2a	2.9a	3a
Grasses	**10a**	**21ab**	**25b**	**19ab**

a, b, c, d; Means with different lower case letters within the same row are siginificantly different at $P < 0.05$.

Table C8. ANOVA summary of the species X season comparisons of elk diets pooled across years at Los Alamos National Laboratory (Within Species Comparisons).

Lifeform/species	**Summer**	**Fall**	**Winter**	**Spring**
One-seed Juniper *(Juniperus monosperma)*	2.7a	1.8a	0.3a	1a
Oak species *(Quercus* species*)*	12.9a	12a	5.7a	11.3a
Mountain Mahogany *(Cercocarpus montanus)*	12a	2.7a	1.8a	4.2a
Apache plume *(Fallugia paradoxa)*	1.6a	1a	6.7a	3a
Russian olive *(Elaeagnus angustifolia)*	4.3a	0.6a	2.8a	7.4a
Skunkbush sumac *(Rhus trilobata)*	5.8a	0b	1.2b	0b
Ponderosa pine *(Pinus ponderosa)*	5.9a	8a	8a	16a
Browse	**61a**	**32b**	**32b**	**53ab**
Mullein *(Verbascum thapsus)*	3.7a	11.8b	14.5b	7a
Annual sunflower *(Helianthus annuus)*	1.8a	3a	2.5a	0a
Scarlet globemallow *(Sphaeralcea coccinea)*	3.4a	5.9a	3.2a	5.3a
Purple prairie clover *(Petalostemum purpureum)*	0.5a	2.6a	4.3a	0ab
Forbs	**19a**	**31a**	**29a**	**19a**
Slender wheatgrass *(Agropyron trachycaulum)*	0.4a	5ab	6.2b	3a
Orchard grass *(Dactylis glomerata)*	1.5a	3a	3.8a	3a
Grasses	**20a**	**37b**	**39b**	**28ab**

a,b; Means with different lower case letters within the same row are significantly different at $P < 0.05$.

Table C9. ANOVA summary of the species X season comparisons of mule deer diets pooled across years at Los Alamos National Laboratory (Within Species Comparisons).

Lifeform/species	**Summer**	**Fall**	**Winter**	**Spring**
One-seed Juniper *(Juniperus monosperma)*	0.1a	2ab	5.3b	9.5a
Oak species *(Quercus* species*)*	17.2a	22a	7.3ab	6b
Mountain Mahogany *(Cercocarpus montanus)*	23a	24a	12.8ab	4.7b
Apache plume *(Fallugia paradoxa)*	4.2a	0a	6.4a	2.5a
Russian olive *(Elaeagnus angustifolia)*	15a	18a	3.9ab	9a
Skunkbush sumac *(Rhus trilobata)*	14.2a	4b	6.3bc	0b
Ponderosa pine *(Pinus ponderosa)*	0.3a	1a	18.7b	15b
Browse	**74a**	**78a**	**61a**	**60a**
Mullein *(Verbascum thapsus)*	0.2a	2a	16.8bc	7b
Annual sunflower *(Helianthus annuus)*	6.7a	1a	0.4a	0ab
Scarlet globemallow *(Sphaeralcea coccinea)*	8.7a	10a	0b	4.7a
Purple prairie clover *(Petalostemum purpureum)*	0a	2a	9.5b	4.2a
Forbs	**26a**	**20a**	**29a**	**33a**
Slender wheatgrass *(Agropyron trachycaulum)*	0a	1a	5.3a	2.5a
Orchard grass *(Dactylis glomerata)*	0a	1a	2a	3a
Grasses	**0.1a**	**2a**	**10a**	**7a**

a,b,c; Means with different lower case letters within the same row are significantly different at $P < 0.05$.

Table C10. ANOVA summary of the species X season comparisons of elk and mule deer diets pooled across years at Los Alamos National Laboratory (Within Season Comparisons).

	Summer		**Fall**		**Winter**		**Spring**	
	June 16th-Sept. 15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
One-seed Juniper	2.7a	0.1a	1.8a	2a	0.3a	5.3b	1a	9.5b
Oak species	12.9a	17.2a	12a	22a	5.7a	7.3a	11.3a	6a
Mtn Mahogany	12a	23b	2.7a	24b	1.8a	12.8b	4.2a	4.7a
Apache plume	1.6a	4.2a	1a	0a	6.7a	6.4a	3a	2.5a
Russian olive	4.3a	15a	0.6a	18b	2.8a	3.9a	7.4a	9a
Skunkbush sumac	5.8a	14.2b	0a	4b	1.2a	6.3b	0a	0a
Ponderosa pine	5.9a	0.3a	8a	1a	8a	18.7b	16a	15a
Browse	**61a**	**74a**	**32a**	**78b**	**32a**	**61b**	**53a**	**60a**
Mullein	3.7a	0.2a	11.8a	2b	14.5a	16.8a	7a	7a
Annual sunflower	1.8a	6.7a	3a	1a	2.5a	0.4a	0a	0a
Scarlet globemallow	3.4a	8.7a	5.9a	10a	3.2a	0a	5.3a	4.7a
Purple prairie clover	0.5a	0a	2.6a	2a	4.3a	9.5b	0a	4.2a
Forbs	**19a**	**26a**	**31a**	**20a**	**29a**	**29a**	**19a**	**33a**
Slender wheatgrass	0.4a	0a	5a	1a	6.2a	5.3a	3a	2.5a
Orchard grass	1.5a	0a	3a	1a	3.8a	2a	3a	3a
Grasses	**20a**	**0.1b**	**37a**	**2b**	**39a**	**10b**	**28a**	**7b**

a,b; Means with different lower case letters within the same season and row are significantly different at $P < 0.05$.

APPENDIX D: SEASONAL DIETARY COMPOSITION

Table D1. Seasonal dietary composition of elk and mule deer diets at Los Alamos National Laboratory during year 1.

	Summer 1998		**Fall 1998**		**Winter 1998**		**Spring 1999**	
	June 16th-Sept.15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Browse								
One-seed juniper	4.8%	0%	T	1%	T	6.3%	2%	7%
Oak species	15.7%	15.2%	11.6%	28.1%	4.2%	9.6%	0%	T
Mountain Mahogany	6.6%	16.3%	3.4%	19.5%	1.3%	15.1%	1.3%	4.3%
Apache plume	3.3%	8.3%	T	0%	5%	8.3%	5%	4.4%
Russian olive	3.5%	21%	T	19%	T	3%	T	4%
Skunkbush sumac	0%	7.4%	0%	6%	0%	4.2%	0%	0%
Buckbrush	0%	0%	0%	0%	0%	T	0%	0%
Pinon pine	0%	0%	0%	1%	0%	0%	0%	18.3%
Coyote willow	9%	0%	0%	0%	0%	0%	0%	0%
Douglas fir	10.7%	0%	0%	0%	0%	0%	0%	0%
Narrowleaf yucca	1.4%	0%	T	0%	4.3%	0%	1.8%	0%
Ponderosa pine	6.4%	0%	3.7%	0%	12%	20%	25.1%	6.8%
Four-wing saltbush	0%	0%	1%	0%	0%	0%	0%	0%
Big sagebrush	0%	0%	0%	0%	0%	0%	15.4%	0%
Total	**62%**	**68%**	**22%**	**75%**	**28%**	**67%**	**51%**	**45%**

T = Trace.

Table D1 Continued. Seasonal dietary composition of elk and mule deer diets at Los Alamos National Laboratory during year 1.

	Summer 1998		**Fall 1998**		**Winter 1998**		**Spring 1999**	
	June 16th-Sept.15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Forbs								
Mullein	7.1%	T	15.2%	4.2%	11%	10.6%	6.7%	6.5%
Annual sunflower	1.4%	12.1%	2.2%	2.2%	0%	1%	0%	0%
White sweet clover	4%	4.3%	0%	1.2%	3.2%	3%	0%	0%
Deer vetch	7.2%	6.2%	0%	2.2%	0%	0%	0%	0%
Aster species	1.3%	1%	0%	0%	0%	0%	0%	0%
Scarlet globemallow	0%	3%	2.2%	12%	0%	0%	1%	2%
Purple prairie clover	0%	0%	1.1%	3%	5%	9%	0%	8.4%
Goldenrod species	0%	0%	1.6%	0%	0%	0%	0%	0%
Fringed sagebrush	0%	0%	12%	0%	0%	0%	0%	8.2%
Fleabane species	0%	0%	0%	0%	0%	0%	1.3%	14%
Tansy mustard	0%	0%	0%	0%	0%	0%	6.6%	0%
Bladderpod species	0%	0%	0%	0%	0%	0%	0%	7.2%
Unident. Forb species	T	4.5%	2.4%	T	0%	1.2%	0%	0%
Total	**21%**	**32%**	**37%**	**25%**	**19%**	**25%**	**16%**	**46%**

T = Trace.

Table D1 Continued. Seasonal dietary composition of elk and mule deer diets at Los Alamos National Laboratory during year 1.

	Summer 1998		**Fall 1998**		**Winter 1998**		**Spring 1999**	
	June 16th-Sept.15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Grasses								
Mutton grass	8.4%	0%	9%	0%	9.5%	0%	5.7%	0%
Canaryreed grass	3.5%	0%	7.5%	0%	0%	0%	1.5%	0%
June grass	2%	0%	7.4%	0%	0%	0%	13.9%	0%
Fescue species	1.4%	0%	9%	0%	12%	0%	0%	0%
Sedge species	T	0%	0%	0%	1.3%	0%	0%	0%
Slender wheatgrass	T	0%	3%	0%	12%	3.5%	0%	3%
Longstyle rush	T	0%	0%	0%	0%	0%	3.7%	0%
Cheat grass	T	0%	T	0%	0%	0%	2.7%	0%
Smooth brome	0%	T	1.1%	T	2.2%	1%	1.5%	T
Blue grama grass	0%	T	T	0%	T	T	0%	0%
Orchard grass	0%	0%	3.6%	T	6.4%	3%	4%	5%
Flatsedge species	0%	0%	T	0%	0%	0%	0%	0%
Little bluestem	0%	0%	T	0%	4.3%	0%	0%	0%
Foxtail barley	0%	0%	0%	0%	5.4%	0%	0%	0%
Total	**17%**	**0%**	**41%**	**0%**	**53%**	**8%**	**33%**	**9%**

T = Trace.

Table D2. Seasonal dietary composition of elk and mule deer diets at Los Alamos National Laboratory during year 2.

	Summer 1999		**Fall 1999**		**Winter 1999**		**Spring 2000**	
	June 16th-Sept.15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Browse								
One-seed juniper	T	T	3.1%	3%	T	4.2%	0%	12%
Oak species	10.1%	19.1%	13%	16%	7.2%	4.9%	22.5%	12%
Mountain Mahogany	17.4%	29.8%	2%	28.6%	2.3%	10.5%	7.1%	5%
Apache plume	0%	0%	2.1%	0%	8.5%	4.4%	0%	T
Russian olive	5.1%	9%	T	17.1%	5%	4.8%	14%	14.4%
Skunkbush sumac	11.6%	21%	0%	3.3%	2.3%	8.4%	0%	0%
Rubber rabbitbrush	0%	0%	0%	5.1%	6.1%	0%	0%	0%
Pinon pine	0%	0%	0%	0%	0%	0%	T	0%
Coyote willow	9%	0%	0%	0%	0%	0%	0%	0%
Douglas fir	0%	0%	0%	0%	0%	0%	0%	8.2%
Narrowleaf yucca	0%	0%	0%	0%	T	0%	0%	0%
Ponderosa pine	5.5%	T	12.4%	2%	4%	17.4%	6.3%	0%
Fourwing saltbush	1.6%	0%	3%	1%	0%	0%	0%	23.2%
Total	**61%**	**80%**	**36%**	**76%**	**36%**	**55%**	**51%**	**75%**

T = Trace.

Table D2 Continued. Seasonal dietary composition of elk and mule deer diets at Los Alamos National Laboratory during year 2.

	Summer 1999		Fall 1999		Winter 1999		Spring 2000	
	June 16th-Sept.15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Forbs								
Mullein	T	0%	8.5%	1.2%	17.9%	23%	6.9%	8.2%
Annual sunflower	2.2%	1.2%	4.1%	T	5%	0%	0%	0%
White sweet clover	T	1.2%	T	3.1%	0%	T	1.9%	1.9%
Deer vetch	0%	3.5%	0%	0%	1.6%	0%	0%	0%
Aster species	0%	0%	0%	0%	0%	0%	0%	0%
Scarlet globemallow	6.7%	14.4%	9.6%	9%	6.3%	0%	9.6%	7.5%
Purple prairie clover	1%	0%	4%	1.1%	3.6%	10%	0%	0%
Fringed sagebrush	0%	0%	0%	0%	0%	0%	0%	T
Fleabane species	0%	0%	0%	0%	0%	0%	T	1.4%
Bladderpod species	0%	0%	0%	0%	0%	0%	0%	1.2%
Unident. Forb species	5.4%	0%	T	5%	3.4%	T	1%	0%
Total	**16%**	**20%**	**27%**	**20%**	**38%**	**34%**	**20%**	**21%**

T = Trace.

Table D2 Continued. Seasonal dietary composition of elk and mule deer diets at Los Alamos National Laboratory during year 2.

	Summer 1999		**Fall 1999**		**Winter 1999**		**Spring 2000**	
	June 16th-Sept.15th		Sept. 16th-Dec. 15th		Dec. 16th-March 15th		March 16th-June 15th	
Lifeform/species	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer	Elk	Mule Deer
Grasses								
Mutton grass	T	0%	5.1%	0%	9.3%	0%	6.4%	0%
Canaryreed grass	7.2%	0%	7.5%	0%	0%	0%	2.9%	0%
June grass	6.4%	0%	9%	0%	8.7%	0%	2.1%	0%
Fescue species	1%	0%	0%	0%	6.1%	0%	6.9%	0%
Slender wheatgrass	T	0%	7.3%	2.1%	T	7%	5.4%	1.9%
Longstyle rush	3.3%	0%	2.5%	0%	0%	0%	1.9%	0%
Smooth brome	1.3%	0%	2%	0%	T	3.1%	2.7%	1.4%
Blue grama grass	0%	0%	T	0%	0%	0%	T	0%
Orchard grass	3%	0%	3%	1.7%	1.3%	1%	1%	T
Little bluestem	0%	0%	0%	0%	T	0%	0%	0%
Total	**23%**	**0%**	**37%**	**4%**	**26%**	**11%**	**29%**	**4%**

T = Trace.

LITERATURE CITED

Alipayo, D., R. Valdez, J.L. Holechek, and M. Cardenas. 1992. Evaluation of microhistological analysis for determining ruminant diet botanical composition. J. Range Manage. 45:148-152.

Allen, C.G. 1996. Elk response to the La Mesa fire and current status in the Jemez Mountains. Pages 179-195 *In* Fire Effects in southwestern forests: Proceedings of the second La Mesa fire symposium. Los Alamos, New Mexico. Gen. Tech. Rep. RM-GTR-286. U.S. Dept. Agr. Rocky Mtn forest and Range Exp. Stn. Fort Collins, CO.

Anthony, R.G., and N.S. Smith. 1974. Comparison of rumen and fecal analysis to describe deer diets. J. Wildl. Manage. 38:535-540.

___________. 1976. Influence of drought on diets and numbers of desert deer. J. Wildl. Manage. 40:140-144.

Baker, D.L., and D.R. Hansen. 1985. Comparative digestion of grass in mule deer and elk. J. Wildl. Manage. 49:77-79.

_________, and N.T. Hobbs. 1987. Composition and quality of elk summer diets in Colorado. J. Wildl. Manage. 46:694-703.

Balice, R.G., S.G. Ferran, and T.S. Foxx. 1997. Preliminary vegetation and land cover classification for the Los Alamos region. Los Alamos, New Mexico. LA-UR-97-4627.

Bartmann, R.M. 1983. Composition and quality of mule deer diets on Piñon-Juniper winter range, Colorado. J. Range Manage. 36:534-541.

Bartolome, J., J. Franch, M. Gutman, and N.G. Seligman. 1995. Technical note: Physical factors that influence fecal analysis estimates of herbivore diets. J. Range Manage. 48:267-270.

Biggs, J. 1996. Biological and floodplain/wetland assessment for environmental restoration program. Operable Unit 1071. TAs 0, 19, 26, 73, and 74. Los Alamos, New Mexico. LA-UR-93-1168.

_______, K. Bennett, and P. Fresquez. 1999. Resource use, activity patterns, and disease analysis of Rocky Mountain elk (*Cervus elaphus nelsoni*) at Los Alamos National Laboratory. Los Alamos, New Mexico. LA-13536-MS.

_______, S. Frybarger, and C. Bare. 2000. Analysis of animal-related collisions at Los Alamos National Laboratory. Los Alamos, New Mexico. LA-UR-00-819.

Blair, R.M., H.L. Short, and E.A. Epps, Jr. 1977. Seasonal nutrient yield and digestibility of deer forage from a young pine plantation. J. Wildl. Manage. 41:667-676.

Bowen, B.B. 1990. Los Alamos climatology. Los Alamos National Laboratory. Los Alamos, New Mexico. LA-11735-MS.

Bryant, L.D., and C. Maser. 1982. Classification and Distribution. Pages 1-59. *In* J.W. Thomas and D.E. Toweill, eds. Elk of North America: ecology and management. Stockpole Books, Harrisburg, PA.

Bubenik, A.B. 1982. Physiology. Pages 125-179. *In* J.W. Thomas and D.E. Toweill, eds. Elk of North America: ecology and management Stockpole. Books, Harrisburg, PA.

Burns, B.M. 1992. Beware elk on roads. *In* Los Alamos Monitor, Dec. 2. Los Alamos, New Mexico.

Carpenter, L.H., O.C. Wallamo, and R.B. Gills. 1979. Forage diversity and dietary selection by wintering mule deer. J. Range Manage. 32:226-229.

Carter, J.L. 1997. Trees and shrubs of New Mexico. Johnson books. Boulder, CO. 534pp.

Church, D.C., and W.H. Hines. 1978. Ruminoreticular characteristics of elk. J. Wildl. Manage. 42:654-659.

Cliff, E.P. 1939. Relationship between elk and mule deer in the Blue Mountains of Oregon. Trans. North Am. Wildl. Conf. 4:646-663.

Collins, W.B., and P.J. Urness. 1983. Feeding behavior and habitat selection of mule deer and elk on northern Utah summer range. J. Wildl. Manage. 47: 646-663.

Connolly, G.E. 1981. Assessing populations. Pages 287-345. *In* O.C. Wallmo, ed. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln.

Dearden, B.L., R.E. Pegua, and R.M. Hansen. 1975. Precision of microhistological estimates of ruminant food habits. J. Wildl. Manage. 39:402-407.

DeWitt Ivey, R. 1995. Flowering plants of New Mexico. 3rd ed. Rio Rancho printing. Albuquerque, New Mexico. 505pp.

Ecology Group. 2001. Wildfire hazard reduction project plan. Los Alamos National Laboratory. Los Alamos, New Mexico. LA-UR-01-2017.

Freddy, D.J. 1983. Efficiency of permanent and temporary pellet plots in piñon-juniper woodlands. J. Wildl. Manage. 47:512-516.

Foxx, T.S., and D. Hoard. 1984. Flowers of the southwestern forests and woodlands. Los Alamos Hist. Soc., Los Alamos, New Mexico. 210pp.

________, and D. Hoard. 1995. Flowering plants of the southwestern woodlands. Otowi Crossing Press, Los Alamos, New Mexico. 208pp.

________. 1996. Biological and floodplain/wetland assessment for Environmental Restoration Program. Operable Unit 1122. TA-33 and TA-70. Los Alamos, New Mexico. LA-UR-93-106.

________. 2000. Out of the ashes: A story of natural recovery. Los Alamos, New Mexico. LALP-01-20.

Geist, V. 1982. Adaptive behavioral strategies. Pages 219-277. *In* J.W. Thomas and D.E.Toweill, eds. Elk of North America: ecology and management. Stackpole Books, Harrisburg, PA.

Green, E.L., L.H. Blankenship, V.F. Cogar, and T. McMahon. 1985. Wildlife food plants: A microscopic view. Tex. Agr. Exp. Stn. RM14/KS6, 160pp.

Gretchen, S., and B.E. Dahl. 1980. Key to selected plant species of Texas using plant fragments. Occasional papers, The Museum Tex. Tech. Univ., Lubbock, Tex. No. 64. 37pp.

Gonzales, T.C., T.S. Foxx, and J. Biggs. 1995. Analysis of animal related accidents in Los Alamos County. Los Alamos National Laboratory, Los Alamos, New Mexico. LA-UR-95-3950.

Hanley, T.A. 1982. The nutritional basis for food selection by ungulates. J. Range Manage. 35:146-151.

Hansen, R.M., A.S. Moir, and S.R. Woodmansee. 1971. Drawings of tissues of of plants in herbivore diets and in the litter of grasslands. Grassland Biome. US International Biological Tech. Report. No. 70. 111pp.

______, and L.D. Reid. 1975. Diet overlap of deer, elk, and cattle in southern Colorado. J. Range Manage. 28:43-47.

______, and R.C. Clark. 1977. Foods of elk and other ungulates at low elevations in northwestern Colorado. J. Wildl. Manage. 41:76-80.

Havstad, K.M. and G.B. Donart. 1978. The microhistological technique: testing two central assumptions in south-central New Mexico. J. Range Manage 31:469-470.

Hobbs, N.T., D.L. Baker, J.E. Ellis, and D.M. Swift. 1981. Composition and quality of elk winter diets in Colorado. J. Wildl. Manage. 41:156-171.

__________, D.L. Baker, and R.B. Gills. 1983. Comparative nutritional ecology of montane ungulates during winter. J. Wildl. Manage. 47:1-16.

Holechek, J.L. 1982. Sample preparation techniques for microhistological analysis. J. Range Manage. 35:267-268.

_________, and B.D. Gross. 1982a. Evaluation of different calculation procedures for microhistological analysis. J. Range Manage. 35:721-723.

_________, and B.D. Gross. 1982b. Training needed for quantifying simulated diets from fragmented range plants. J. Range Manage. 35:644-647.

_________, M. Vavra, and R.D. Pieper. 1982. Botanical composition determination of range herbivore diets: a review. J. Range Manage. 35:309-315.

_________, M. Vavra, and R.D. Pieper. 1984. Methods for determining the botanical composition, similarity, and overlap of range herbivore diets. Pages 425-473. *In* Developing Strategies for Rangeland Management. Westview Press, Boulder, CO.

_________, and R. Valdez. 1985. Magnification and shrub stemmy material influences on fecal analysis accuracy. J. Range Manage. 38:350-352.

_________, R.D. Pieper, and C.H. Herbel. 1998. Range management: principles and practices. 3rd ed. Prentice-Hall Inc., New Jersey. 542pp.

Howard, G.S., and M.J. Samuel. 1979. Atlas of epidermal plant species fragments ingested by grazing animals. US Dept. Agr. Tech. Bul. 1582, 143pp.

Howard, V.W., J.L. Holechek, R.D. Pieper, K. Green-Hammond, M. Cardenas, and S.L. Beasom. 1990. Habitat requirements for pronghorn on rangeland impacted by livestock and net wire in eastcentral New Mexico. New Mexico Agr. Exp. Stn. Bull. 750.

Hubbard, R.E., and R.M. Hansen. 1976. Diets of wild horses, deer, and cattle in the Douglas Mountain Area. J. Range Manage. 30:116-118.

Hunt, H.M. 1979. Summer, autumn, and winter diets of elk in Saskatchewan. Canadian Field-Naturalist. 93:282-287.

Johnson, M.K., and H.A. Person. 1981. Esophageal, fecal and exclosure estimates of cattle diets on a longleaf pine-bluestem range. J. Range Manage 34:232-235.

Joseph, J.J. 1995. Seasonal food habits of mule deer at the Corona range and livestock research ranch. M.S. Thesis, New Mexico State Univ., Las Cruces. 56pp.

Kessler, W.B., W.F. Kasworm, and W.L. Bodie. 1981. Three methods compared for analysis of pronghorn diets. J. Wildl. Manage. 45:612-619.

Kingery, J.L., J.C. Mosley, and K.C. Bordwell. 1996. Dietary overlap among cattle and cervids in northern Idaho forests. J. Range Manage. 49:8-15.

Koch, S.W., T.K. Budge, and R.G. Balice. 1997. Development of a land cover map for Los Alamos National Laboratory and vicinity. Ecology Group, Los Alamos National Laboratory, Los Alamos, New Mexico. LA-UR-97-4628.

Kufeld, R.C. 1973. Foods eaten by Rocky Mtn elk. J. Range Manage. 26:106-113.

_________, O.C. Wallmo, and C. Feddema. 1973. Foods of Rocky Mtn mule deer. USDA Forest Service Research Paper. RM-111. 31pp.

Lang, E.M. 1957. Deer of New Mexico. Bulletin no. 5. Santa Fe: New Mexico Dep. Game and Fish. 41pp.

_________. 1958. Elk of New Mexico. Bulletin no. 8. Albuquerque: New Mexico Dep. Game and Fish. 33pp.

Leslie, D.M., E.E. Starkey, and M. Vavra. 1984. Elk and deer diets in old-growth forests in western Washington. J. Wildl. Manage. 48:762-775.

Lindzey, F.G., W.G. Hepworth, T.A. Mattson, and A.F. Reeves. 1997. Potential for competitive interactions between mule deer and elk in the western United States and Canada: a review. Wyoming Cooperative Fisheries and Wildlife Research Unit. Laramie, Wyoming. 82pp.

Los Alamos National Laboratory. 2001. http://weather.lanl.gov/ LANL_Met_Archives/as1998, 1999, and 2000.gif

Mackie, R.J. 1970. Range ecology and relations of mule deer, elk, and cattle in the Missouri River Breaks, Montana. Wildlife Monogr. No. 20. 79pp.

Mangold, L.K. 1997. Elk food habits in the mechanically disturbed piñon-juniper woodlands of the Gila National Forest, New Mexico. M.S. Thesis, New Meixico State Univ., Las Cruces. 61pp.

Martin, D.J. 1954. Features on plant cuticle. An aid to the analysis of the natural diet of grazing animals, with especial reference to Scottish Hill sheep. Trans. Bot. Soc. Edin., Vol. XXXVI. PT. IV. 13pp.

McInnis, M.L., M. Vavra, and W.C. Krueger. 1983. A comparison of four methods used to determine the diets of large herbivores. J. Range Manage. 36:302-306.

Mohammad, A.G., R.D. Pieper, J.D. Wallace, J.L. Holechek, and L.W. Murry. 1995. Comparison of fecal analysis and rumen evacuation techniques for sampling diet botanical composition of grazing cattle. J. Range Manage. 48:202-205.

Mower, K.J., and H.D. Smith. 1989. Diet similarity between elk and deer in Utah. Great Basin Nat. 49:552-555.

Nelson, J.R., and T.A. Leege. 1982. Nutritional requirements and food habits. Pages 323-367 *In* J.W.Thomas and D.E. Toweill, eds. Elk of North America: ecology and management. Stockpole Books, Harrisburg, PA.

____________. 1982. Relationships of elk and other large herbivores. Pages 415-441 *In* J.W.Thomas and D.E. Toweill, eds. Elk of North America: ecology and management. Stockpole Books, Harrisburg, PA.

Oosting, H.J. 1956. The study of plant communities. W.H. Freeman and Company, San Francisco. 440pp.

Owen, M. 1975. An assessment of fecal analysis technique in waterfowl feeding studies. J. Wildl. Manage. 39:271-279.

Potter, L.D., and S. Berger. 1977. Deer-burro utilization and competition study, Bandelier National Monument. Unpublished report on file at Bandelier National Monument, New Mexico. 44pp.

_________. 1977. Histological illustrations. Guide to identification of forage plants in fecal analysis. Bio. Dept. Univ. New Mexico, Albuquerque. 14pp.

Racinez, E., and T. Foxx. 1999. A notebook of sedges and rushes of the Jemez Mtns. Los Alamos National Laboratory, Los Alamos. LA-UR-99-5185.

Raymer, D.F. 1996. Biological and floodplain/wetland assessment for environmental restoration program. Operable Unit 1082. TAs 11, 13, 16, 24, 37, and 38. Los Alamos, New Mexico. LA-UR-93-4182.

Rowland, M.M., A.W. Alldredge, J.E. Ellis, B.J. Weber, and G.C. White. 1983. Comparative winter diets of elk in New Mexico. J. Wildl. Manage. 47:924-932.

Salisbury, M. 1995. Biological assessment for environmental restoration program. Operable Unit 1111. TAs 6, 7, 22, 58, and 62. Los Alamos, New Mexico. LA-UR-95-4118.

Sanders, K.D., B.E. Dahl, and G. Scott. 1980. Bite count vs. fecal analysis for range animal diets. J. Range Manage. 33:146-149.

SAS Institute Inc., SAS/STAT *User's Guide, Version* 8, Cary, NC: SAS Institute Inc., 1999. 3884 pp.

Short, H.L., D.E. Medin, and A.E. Anderson. 1965. Ruminoreticular characteristics of mule deer. J. Mammal. 46:196-199.

_________. 1971. Forage digestibility and diet of deer on southern upland range. J. Wildl. Manage. 35:698-706.

_________, W. Evans, and E. Boeker. 1977. The use of natural and modified piñon pine-juniper woodlands by deer and elk. J. Wildl. Manage. 41:543-559.

_________,1977. Food habits of mule deer in a semi desert grass-shrub habitat. J. Wildl. Manage. 30:206-209.

_________. 1978. Ruminoreticular characteristics of elk. J. Wildl. Manage. 43:654-659.

_________. 1979. Deer in Arizona and New Mexico: their ecology and a theory explaining recent population declines. USDA-Forest Service Technical Report RM-70. 25pp.

_________. 1981. Nutrition and metabolism. Pages 99-127 *In* R.E. McCabe and L.R. Jahn, eds. Mule deer and black-tailed deer of North America. Univ. Nebr. Press. Lincoln and London.

Slater, J. and R. J. Jones. 1971. Estimation of diet selected by grazing animals from microscopic analysis of the feces. A warning. The J. Austr. Inst. Agr. Sci. 37:238-239.

Smith, J.G. 1952. Food habits of mule deer in Utah. J. Wildl. Manage. 16: 148-155.

Smith, L.W., H.K. Goering, D.R. Waldo, and C.H. Gordon. 1971. In-vitro digestion rate of forage cell wall components. J. Dairy Sci. 54:71-76.

_________, H.K. Goering, and C.H. Gordon. 1972. Relationships of forage compositions with rates of cell wall digestion and indigestibility of cell walls. J. Dairy Sci. 55:1140-1147.

Smith, A.D. and L.J. Shandruk. 1979. Comparison of fecal, rumen, and utilization methods for ascertaining pronghorn diets. J. Range Manage. 32:275-279.

Snyder, W.A. 1976. Changes in New Mexico's mule deer population and management. Proc. West. Assoc. Game and Fish Commissioners. 56:404-407.

Sparks, D.R., and J.C. Malachek. 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range Manage. 21:264-265.

Storr, G.M. 1961. Microscopic analysis of feces, a technique for ascertaining the diet of herbivorous mammals. Aust. J. Biol. Sci. 14:157-164.

Stubbendieck, J., S.L. Hatch, and C.H. Butterfield. 1997. North American range plants. 5th ed. Univ. of Nebr. Press, Lincoln and London. 499pp.

Tafoya, J.J. 2000. A comparison of elk, mule deer, and Cues deer diets from pinyon-juniper woodlands in southwestern New Mexico. M.S. Thesis, New Mexico State Univ., Las Cruces. 54pp.

Tierney, G.D., and T.S. Foxx. 1980. Status of the flora of the Los Alamos National Environmental Research Park. Vol. I. Los Alamos Scientific Laboratory. Los Alamos, New Mexico. LA-8050-NERP.

___________, and T.S. Foxx. 1982. Floristic composition and plant succession on near-surface radioactive waste disposal facilities in the Los Alamos National Laboratory. Los Alamos, New Mexico. LA-9219-MS.

___________, and T.S. Foxx. 1984. Status of the flora of the Los Alamos National Environmental Research Park, a historical perspective. Vol. II. Los Alamos National Laboratory. Los Alamos, New Mexico. LA-8050-NERP.

Todd, L.W., and R.M. Hansen. 1973. Plant fragments in the feces of bighorns as indicators of food habits. J. Wildl. Manage. 37:363-366.

Vavra, M., R.W. Rice, and R.M. Hansen. 1978. A comparison of esophageal fistula and fecal material to determine steer diets. J. Range Manage. 31:11-13.

________, and J.L. Holechek. 1980. Factors influencing microhistological analysis of herbivore diets. J. Range Manage. 33:371-374.

Wallmo, O.C., L.H. Carpenter, W.L. Regelin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30: 122-127.

____________, and W.L. Regelin. 1981. Rocky Mountain and Intermountain habitats: Part 1. Food habits and nutrition. Pages 387-398 *In* R.E. McCabe and L.R. Jahn, eds. Mule deer and black-tailed deer of North America. Univ. Nebr. Press. Lincoln and London.

White, G.C. 1981. Biotelemetry studies on elk. Los Alamos Scientific Laboratory. Los Alamos, New Mexico. LA-8529-NERP.

Wolters, G.I. 1993. Elk effects on Bandelier National Monument meadows and grasslands. Pages 196-205. *In* Fire effects in southwestern forests: Proceedings of the second La Mesa fire Symposium. Los Alamos New Mexico. Gen. Tech. Rep. RM-GTR-286. US Dept. of Agr., Rocky Mtn Forest and Range Exp. Stn. Fort Collins, CO.

Los Alamos NATIONAL LABORATORY
Los Alamos, New Mexico 87545